Vol. XIX, No. 6 PSYCHOLOGICAL REVIEW PUBLICATIONS November, 1912

THE

Psychological Review

EDITED BY

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HOWARD C. WARREN, Princeton University (*Index*)

JAMES R. ANGELL, University of Chicago (*Monographs*) and

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PUBLISHED BI-MONTHLY BY

PSYCHOLOGICAL REVIEW COMPANY

41 NORTH QUEEN ST., LANCASTER, PA.

AND PRINCETON, N. J.

AGENTS: G. E. STECHERT & CO., London (2 Star Yard, Carey St., W. C.); Leipzig (Hospital St., 20); Paris (76 rue de Rennes);

Entered as second-class matter July 13, 1897, at the post-office at Lancaster, Pa., under Act of Congress of March 3, 1879.

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PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

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VOL. XIX. No. 6 November, 1912

THE PSYCHOLOGICAL REVIEW

THE NATURE OF PERCEIVED RELATIONS

BY KNIGHT DUNLAP

The Johns Hopkins University

§ 1. The General Problem

I shall attempt here to justify a certain way of considering perceived relations; a way which is not new, but which is radically incompatible with prevalent psychological theories, and which may therefore be expected to find little favor. In order to explain the view as fully as possible it is necessary to examine certain other views held on the perception of relation and to compare them with the one in question.

Differences in general psychological theory, as well as differences in terminology, render it almost impossible to state the positions of various psychologists in any common terms. Who can confidently determine, for example, the relations of the "Psychic Processes" of Wundt's *Outlines* to the "Modes of Being Conscious" and "Mental Processes" of Stout's *Manual*, and to the "Experiences" of Calkin's *First Book?* I shall therefore ascribe definite meaning to the statements of contemporary writers in a very few cases only, where the meaning seems to me to be unmistakable. In other cases I shall interpret very tentatively, or refrain from interpreting altogether.

I do not now intend to discuss "imageless thought," but am willing to concede, for the sake of argument, that relations are not perceived in temporal disjunction from sensible factors. Furthermore, I have no present concern with "forms of thought" or "perception qualities." Although the examination of these is well worth while, it has no essential place in the

consideration which I am here undertaking. As for "Bewusstseinslagen" and similar fabrications of the Germans; these terms have so little definite meaning that we would do well to exclude them and translations of them from English psychology.

No one, so far as I am aware, not even Bradley, really disputes the statement that relations exist, and are perceived.[1] No one, I suppose, would be less ready to challenge the statement that red and blue are apprehended than the statement that differences (in hue or in brightness) are apprehended. The only differences of opinion in regard to the perception of relations seem to be about (1) the nature of the perceived relations and (2) the nature of the perceiving of the relations.

Let us examine the statement that *relations exist.* By *relation* I mean such a thing as *difference* or *intermediacy.* Thus, green differs from red, and from blue, and each of these differs from blue-green. These differences are so definite that the difference between green and blue-green can positively be said to be less than the difference between green and red. Furthermore, the blue-green is in a relation of intermediacy to the blue and the green; a relation which may not be a new element, but may be merely the complex of the specific differences involved.

By existence, as applied to a relation, I mean exactly what I mean by the same term as applied to a sensible.[2] The green,

[1] The possibility that the essential 'mental' difference between man and the lower animals lies in the perception of relations by man, and the non-perception of relations by animals, is worthy of consideration. The results of the experiments on the learning processes of animals rather favor this view. It may be that animals, or certain animals, are so constituted that, for example, they are not aware of a difference between red and green successively seen, although they may react differently to the red and to the green, and to green preceded by red and green not preceded by red. The colors may be perceived, and may be different, and may provoke different reactions, and yet the difference not be perceived.

[2] *Sensible* seems to me to be the least ambiguous term in present use for the simple object of sense perception: the objective meaning of 'sensation.' Professor Bain uses *sensum,* to which there are several objections, the confusion in sound between *sensa* and *senses* being the practical one, and the logical implication of the past participle the most important. *Sentiendum* would be a better term. Alexander (*Proc. Arist. Soc.,* X., 1909–1910, p. 7) and Wodehouse (*The Presentation of Reality,* 1910, p. 60), use Bain's term; but Wodehouse also (p. 12) uses *sensatum* (!)

I shall use *sensible* where I distinctly mean the 'sensible quality.' In the historical survey, however, I am compelled to use 'sensation' even when it is clear that authors

the red, and the difference between them, are alike factual. This statement does not necessarily involve the assumption that in all cases the relations are exactly what they are judged to be. I may (possibly) have a fallacious awareness of a relation. The judgment that two reds differ in intensity may not mean, in a certain case, that the intensities of the two sensibles actually differ. On the other hand, it may be that a relation is whatever it is perceived to be.[1] Nor do we imply, by the affirmation of existence, that variations in degree of relation are of the same order as variations in degree of sensibles.

The grade of reality assigned to relations is therefore such as will account for the facts that (1) they function in complexes with sensibles, and (2) they are perceived along with sensibles. To this grade they are as a matter of fact admitted by practically every psychologist, as will appear. Our business now is to investigate the nature of these relations.

The various theories concerning the nature of perceived relations have been involved with theories of the nature of the perception of relations to such an extent that the two topics must perforce be considered together, the desirable separation being made subsequently, in so far as it is possible to make it at all. The theories may be reduced to six types, which are: (1) the sensational theory; (2) the scholastic theory; (3) the representative theory; (4) the kinesthesis theory; (5) the theory of relational states of consciousness; and (6) the theory of relational elements in content. To some of these types there are indefinite subtypes. They are not of equal logical rank; but the division is justified by its practical convenience.

have meant by it 'sensible,' since a change of terminology often changes an argument. Perhaps in the course of time we shall be able to use 'sensation' for *sentiens* alone, but for the present the term, while not so promiscuous in its connections of meaning as is 'mental,' is nevertheless so loose that it ought to be excluded from scientific usage as far as possible.

[1] I am assuming that relations really exist, whether perceived or not, if the sensibles which might be perceived in the relation, exist. When blue, blue-green, and green are presented to a subject who does not perceive the intermediacy of the blue-green with regard to the other two, they are nevertheless in the same relation of intermediacy as when it is perceived. This assumption may however be rejected, without damage to the exposition.

§ 2. The Sensational Theory of Perceived Relations

Relations are said to be sensations. This is the theory which Thomas Brown accuses Condillac of holding.[1] It is true that these, and all other apparently non-sensational 'states of mind' are called by Condillac 'transformed' sensations; but the adjective, as Brown points out, does not materially alter the case. No matter how sensations are 'transformed,' they are still either (1) sensations or else (2) no longer sensations, but *ipso facto* something different in kind from sensations, in which case the statement is not as to the nature of sensations (which is by implication *sui generis*), but is merely as to their origin. Only one who holds to the first alternative is properly to be classed as a sensationalist in regard to relations.

What Condillac held concerning perceived relations is probably not what Brown understood him to mean, but merely the commonplace representative doctrine. Since no modern writer, so far as I am aware, upholds the strictly sensational theory[2] (a theory which would indeed tax the ingenuity of any one who should attempt to defend it!), we may legitimately ignore it.

§ 3. The Scholastic Doctrine of Perceived Relations

Scholasticism and representationism are so closely related in their treatment of relations, that it is sometimes difficult to determine which theory a certain writer comes the nearer to.[3]

[1] Brown, 'Lectures on the Philosophy of the Human Mind,' Lecture XXXIII.

[2] By sensationalism in regard to relations, I understand a theory which makes perceived relations out to be sensibles; not a theory which merely affirms them to be *intuitively perceived*. In order to be classed as a sensationalist, therefore, one must hold that relations are sensations of one or more of the accepted modalities, or must identify them with a new mode, comparable to the accepted modes of vision, audition, etc.

Titchener, for example, *if* he really holds definite relations to be nothing more nor less than definite kinesthetic sensations, or complexes of kinesthetic sensations (I do not accuse him of so holding), is certainly a sensationalist.

James defines sensationalism as the doctrine that no 'feelings of relation' exist, and therefore that no relations are actually perceived. I know of no evidence that any one ever held such a stupid doctrine; certainly Hume and Bain, the only two whom James specifically names, are clearly and emphatically not guilty.

[3] See Maher, 'Psychology,' Chapter IV., § The Scholastic Doctrine of Species; and Chapter VI.

By 'scholastic doctrine' I mean here the particular doctrine of Thomas Aquinas,

Nevertheless, when clearly stated, the two theories are distinct, and many psychologists are so explicit that we can decide which doctrine they hold.

The scholastic theory holds that sensation is an activity of the mind, which, on a somewhat low plane, cognizes an extramental reality. Sensation is not primarily an object cognized but is the *sentiens* of the object. Scholasticism is therefore sharply distinguished from representationism, in its doctrine of sensation. Relations, according to scholasticism, are cognized by an activity which is not only higher in degree than is the activity of sensation, but is also higher in kind.

"We fix upon a certain attribute of two or more objects, and comparing the objects pronounce them to be alike or unlike in this feature. This judgment is evidently distinct from the sensation or image of either object, though it presupposes sensations or images of both. It implies, in fact, a mental act distinct from the related impressions by which the relation subsisting between them is apprehended in an abstract manner. To affirm that the taste of a certain claret is like that of sour milk, or that the earth resembles an orange, there is required in addition to the pair of compared ideas a superior force which holds them together in consciousness, and discerns the relation of similarity between them. Neither the mere coexistence, nor still less the successive occurrence of the two impressions, could ever result in the perception of a relation between them, unless there be a third distinct activity of a higher kind to which both are present, and which is capable of apprehending the common feature."[1]

"*Intellect*, in its old and proper signification, as a higher rational activity superior to sense, awakened, indeed, to exercise by the latter, but transcending its range . . . makes intelligible the stream of change disclosed in sensation. . . . Now in normal perception these sensuous and intellectual elements are closely interwoven, and it may require careful attention and

which has survived as the official theory of the Catholic Church. On this doctrine, I assume the statements of Maher, in his 'Psychology,' and in his article 'Intellect' in the *Catholic Encyclopedia*, to be conclusive. This is commonly called the 'intellectualist' doctrine, and opposed to a vaguely conceived 'Sensationalism.' See James, *Principles of Psychology*, I., 244–245.

[1] Maher, 'Psychology,' Chapter XII., § Comparison and Judgment.

reflection to separate them; but none the less are they radically different in kind."[1]

"Even in simple sensations, such as those of sight, there is genuine psychical activity of a certain kind; for the mind truly reacts to the physical stimulus by a conscious state. Still, compared with thought, sensuous life is relatively recipient and passive."[2]

Angell, in his *Psychology*, especially in the chapter on "The Consciousness of Meaning and the Formation of Concepts," takes the scholastic ground in regard to the perception of relations. The keynote of the chapter named is given in the statement that "The mind shows itself from the very outset as a relating activity."[3]

It seems reasonable to conclude that a 'mind' capable of the 'higher,' or intellectual, activity, is capable of submitting the lower, or sensational, activity to the higher, and so cognizing both it and its relations, as well as the relations in the external world. In its doctrine of the intellect, scholasticism has therefore not only a consistent account of the perception of real relations, but it has also a logical basis for the doctrine of introspection; a basis sadly wanting in systems which deny the 'higher' activity.[4]

In its doctrine of a mental activity which 'mirrors' the external world, scholasticism is approached rather closely by the representationism which it despises, or at least by the simple kind of representationism which grew directly out of it. For even if the sensational activity be primarily not representative, but intuitive; when it is introspected or cognized by the intellect it becomes a representation, although not a copy, of the external reality which, as a mental activity, it cognized. So too, Stout's doctrine of perception, and James's doctrine, although primarily intuitive, become representative, and explicitly so, through the function of introspection.[5]

[1] Maher, *op. cit.*, Chapter VII., § Intellect Usually Ignored.

[2] Maher, *op. cit.*, Chapter XIV., § Thought an Activity.

[3] Angell, 'Psychology,' 4th ed., Chapter X. An older work which takes the same attitude, although strongly influenced by Brown's representationism, is Abercrombie's 'Inquiries Concerning the Intellectual Powers,' especially in Part III., Section 4.

[4] See Maher, *op. cit.*, Chapter XI., § Reflexion and Self-consciousness.

[5] See my discussion of "The Case against Introspection," PSYCHOLOGICAL REVIEW, 1912, Vol. XIX., pp. 406–410.

§ 4. The Representative Doctrine of the Perception of Relations

The theory of relation-perception to the consideration of which we now turn, I call the representative theory, because it is founded on, or rather is a part of, the representative theory of perception to which I have already alluded. According to this doctrine, which apparently has its modern beginning in Descartes, nothing extra-mental is experienced: the things experienced are either the mind's own modifications (the 'simpler' representationism), or something which somehow gets into the mind (the 'complex' representationism),[1] and in either case represent (not necessarily resemble) the external reality which is believed to exist, but to be perceived only in this odd way.

The rise of representationism was due to the demand that psychology be put to the practical test, as well as to the logical test. Psychology may be said to have become experimental in the hands of Descartes. The scholastic doctrine affirms the possibility of observing two distinct things: the external reality, and the sensuous activity in the mind which 'mirrors' that reality, or at least 'mirrors' certain attributes of that reality. If one puts this doctrine to the trial of observation, and finds not two things, but only one, he is apt to conclude that he either does not observe any external reality, or that he does not observe any internal process. For Descartes and for many since his time, the first alternative has seemed the more reasonable. Neither the empiricism of Berkeley, nor the idealism of Fichte, nor the realism of Reid succeeded in seriously hampering the progress of representative dualism, and with the advent of the so-called 'New Psychology' it became the official metaphysics of psychology. Some psychologists take it straight; some prefer it with a scholastic flavor; some qualify it with a brief statement of a quasi-Spinozistic belief that ultimately the mental modification and the external thing are the same; but nearly all, especially the experimental psychologists, accept it.

Representationism, being the child of scholasticism, starts its housekeeping with practically the same sort of mental

[1] The distinctions as drawn by Hamilton, 'Metaphysics,' Lecture XXI.

furniture as that found in the maternal house. The mental content of the latter is limited to sensations and feelings: the lower activities of the mind with their relations, which are objects of knowledge for the higher activity. So representationism assumes that the mental modifications, or mental processes, or ideas, which the mind may know, are to be completely accounted for as sensations (with copies, or images of these) and feelings. And like scholasticism, it assumes that the mind cognizes these contents and their relations (or that these somehow get cognized or experienced). The perception of the relations among the mental objects is assumed as an ultimate fact, just as naïvely as the physicist assumes the ability to compare 'physical' objects.[1] The business of the psychologist, in so far as relations are concerned, is apparently limited to the examination of the conditions under which sensations (and feelings) may be compared[2] with possibly an attempt to classify relations.[3] This latter procedure, I suspect, is considered by contemporary psychologists as an unprofessional infringement on the rights of logic.

It might be held that not all relations of mental states are perceived directly, but only the relations of certain classes of

[1] It is not worth while to pile up specific citations on this point. Any text-book of psychology (with the exceptions of those herein mentioned as taking a different view), opened in any chapter, will do. The exposition of Weber's law, in the ordinary text-book, assumes the perception of relations with great explicitness, and the usual exposition of Fechner's formula assumes even the perception of *differences between differences*.

[2] Bain, for instance, in 'The Senses and the Intellect,' in the pages preceding Chapter I. of The Intellect, says: "The transition from one impression to a second gives the consciousness of difference or discrimination; the occurrence of likeness in the midst of change yields a new and distinct effect, the effect of agreement." Bain's representationism is tinctured with scholasticism: see *op. cit.*, Introduction, Chapter I., 1, where he assumes the cognizance of external reality. Yet James instances Bain as a typical "sensationalist" in regard to relations.

[3] The classifications of Locke, Hume, Abercrombie, Brown, and Upham are given at the end of this paper for their historical interest. Locke, 'Essay,' Vol. I., Book II., Chapter XXV. (especially § 8); Book II., Chapter XI.; and Book IV.; makes it clear that perceived relations are ultimate, and on a higher plane than the 'simple ideas of sensation.' Hume, although treating relations at considerable length in the 'Treatise,' Book I., Part I., §§ 4, 5; and Part III.; is less clear than Locke. He seems to have abandoned the scholastic doctrine of the perception of relations on a plane higher than that of sensation, but certainly is explicit as to their perceptibility and ultimacy.

states; the relations of the others might well be perceived indirectly, or representatively, through the relations of the favored classes. This is a rather simple extension of the fundamental principle of representationism, and might be based on any class of sensations, although kinesthetic sensations are the only ones which actually seem to have been supposed to function as the universal bearers of perceived relations. This theory is given a separate place below, under the heading of "the kinesthesis theory."

The representative treatment of relations seems logically consistent with the main doctrine of representationism. One who holds to that doctrine, it seems to me, must deny the existence of 'mental states' of relation, or else involve himself in embarrassing absurdities. The known content is constituted by 'modifications,' or 'processes,' or 'states' of the 'mind,' which are brought about, or in some way correspond to, certain external things. Now, two of the 'states' may be different, just as the objects they represent are different; but the difference between these 'states' can not possibly be a third 'state,' any more than the difference between iron and steel can be a third metal. If the 'mind' may be modified in one way, and then in another way, and if these ways are really different, and if each of these is perceptible without the aid of any other 'state,' so is their difference, or any other relation whose conditions are given by the two 'states' themselves. If there should be a 'mental state' of difference, it would necessarily include the two impressions so related, or else it would not be the particular difference between them; hence it could scarcely be elemental, but rather would be a specific combination of the two impressions.

So far, I have been discussing the simpler form of representationism. I do not see that the case would be essentially different with the more complex form. Assume that the furniture of the mind is something injected into it from without, instead of being carved out of the 'mind' stuff itself, and what I have said seems to apply. This problem is not very acute, however, for complex representationism, if it ever existed in a definite form, is not fashionable today. I have been merely

trying to show that the admission or rejection of relational elements of content, on the representative hypothesis, at least in its simpler form, is a definite problem, which does not especially concern those who have not accepted the creed of representationsim.

§ 5. The Kinesthesis Theory of the Perception of Relation

The most reasonable construction to be put on the statements made by Professor Titchener, in the Division headed "Thought" in the Second Part of his 'Text-Book of Psychology,' is that he holds that the only relations directly perceived are those subsisting between, or 'carried' by, kinesthetic sensations. His statements are, however, not very definite, and I shall not insist that this is what he intended to express, but shall discuss the theory suggested by his statements as being possibly what he holds.

"In the author's experience, the feelings of relation are never simple. They are ordinarily matters of motor empathy; the relation is acted out, though in imaginal rather than in sensory terms. Sometimes the kinesthetic images are accompanied by a visual image, itself usually symbolic; sometimes they are strongly colored by pleasantness-unpleasantness. Whenever the relation is conscious, it is indubitably a complex of the familiar elements. But the path of habit leads, here as elsewhere, from the conscious to the unconscious; a relational word may switch one's ideas into a new direction, without any traceable representation of the relation within consciousness. It is, then, conceivable that the imageless relations of the text mark a halfway stage between kinesthetic set and unconsciousness; that, in certain individuals, a faint glow of consciousness still plays about excitatory processes which, in other individuals, are altogether unconscious. It is more probable that a systematically controlled introspection will, in all cases of consciousness, reveal the imaginal character of the feeling of relations."[1]

Now this might possibly be said to be a statement which

[1] Titchener, 'Text-book of Psychology,' § 140.

does not concern relation *per se*, but which concerns merely the doctrine that a relation can appear alone in consciousness: that one can think of (or perceive) a relation without any terms related;—a doctrine which Professor Titchener is in fact principally engaged in combating in the portion of his book to which I refer. The statement quoted, however, occurs in a section headed "The Alleged Elementary Process of Relation," which opens with a specific reference to the James theory. Moreover, we are promised in Part I. (§ 10): "These relational processes we discuss in Part II.": and the discussion from which I have quoted, and of which the quotation is fairly characteristic, is the only one which corresponds to the promise. It is regretable that Professor Titchener has not been more explicit, and has not gone into detail with regard to the perception of relations as well as to relations in thought; but we must be content with his statements as they are.

Let me again remind the reader that I am not supporting the doctrine of 'imageless thought' or any other doctrine of the perception of bare relations (or of the perception of bare sensations either). In so far as Professor Titchener claims that the relation in thought is always acted out, in terms of some sort, his results seem to me unquestionable. Moreover, I admit that his analysis of 'conscious attitudes' into kinesthetic 'sensations' reduces these things into the only terms in which they could possibly be intelligible. But this does not touch the problem of the perception of relations, except to intensify it.

Suppose we fall back, for an example, on our old friend difference. If, when I am conscious (in thought) of difference between a and b, it is because the difference is acted out by kinesthetic 'sensations' or images, it must be that one kinesthetic complex functions for a and another for b. We have therefore in addition to a and b the kinesthetic complexes a' and b'; and if the difference between a' and b' represents the difference between a and b, and the differences between the members in a certain number of other pairs, a_1b_1, a_2b_2, etc.; then it is quite conceivable that the recurrence of a' and b' may represent this generalized difference, without any of the terms

to which the difference ultimately applies being present. But this is not possible unless the difference between *a'* and *b'* is perceived; and hence this process of kinesthetic abstraction is in no way the explanation of the perception of difference.

It is to be presumed, since the discussion from which I quote is of the 'alleged elementary process of relation,' that the kinesthetic processes are involved, not only in the quasi-imageless thought of relation, but in the case also where the terms related are clearly present in consciousness. Hence the construction which we must put on the theory involves the conclusion that the difference between two color 'sensations,' *a* and *b*, can not be perceived, but that each evokes a motor response, *a'* and *b'*, and that the difference between these motor responses is perceived, passing, in consciousness, as the difference between *a* and *b*. For, if no difference can be perceived between two 'sensations,' the adding of any number of new 'sensations' or images could not conceivably help the situation, unless some were finally added which permitted their difference to be noticed. A man might react in one way to one 'sensation' and in another way to another, but if he perceived difference neither between the primary 'sensations,' nor between the kinesthetic 'sensations' accompanying them (*i. e.*, the 'sensations' due to the reaction), he would perceive no difference. Animals may be thus limited in their experience, but we are not. It is the fact that we do, somehow, experience relations, which permits us to talk about them and to theorize as to how they are perceived.

An apparent concession to relations other than those of kinesthetic 'sensations' is made by Professor Titchener in his treatment of *meaning*,[1] in which he asserts that meaning is nothing but "context," which may be "carried in imaginal terms" although "originally, meaning is kinesthesis." In this section, I understand the author to mean that the representative function, in regard to relations, which he treats in other places as belonging to kinesthetic sensations and images only, may, by a process of substitution, come to be carried on by imagery of other sorts. This does not however materially alter

[1] Titchener, *op. cit.*, 103.

the situation. A present sensation, let us say, *means* a situation which occurred in the past through the arousal of an image drawn from that past situation: but this is possible only if the image *means* the past situation; otherwise it is merely one more item in the present object.

The kinesthetic theory, assuming that such a theory is actually held, requires an amount of evidence which has not yet been produced. The fact, if proved, that kinesthetic sensations or images accompany all our thoughts of relation, and all our perceptions of relations, proves nothing.[1] Moreover, why should we stop in the midst of a theory? If the seeming relations between green and red are supposed to be relations between complexes of kinesthetic sensations, or any function of kinesthetic sensations, why not assume that the green and the red also are really only kinesthetic complexes?

Any theory of relations which bases them on motor processes is an inversion of the normal order of horse and cart. The only assignable reason for the fact that small differences in stimulus produce large differences in reaction is found in the fact of the perceived differences in the sensations. A difference in sensation which produces no important difference in reactions while it is unnoticed, may, when noticed, produce a maximal difference. There is no direct correspondence between degree of sensation difference and degree of reaction difference. Suppose some one sorting different colored beads, and rejecting all which differ slightly from a given standard. If the standard be yellow, a blue bead may be rejected a little more quickly than a slightly greenish one; but the slight difference in time is inconsiderable in comparison with the difference between the keeping and the rejecting at all. My point here, however, is that a person who has had little training in observ-

[1] I am inclined to believe that Professor Titchener's finding only kinesthetic sensations when he looks for relations between other objects, is a proof (although none was needed) that he is an exceedingly acute and careful *introspector*. I have pointed out in a previous paper (PSYCHOL. REV., XIX., p. 411) that 'introspection,' divested of its mythological suggestion of the observing of consciousness, is really the observation of bodily sensations (sensibles) and feelings (feelables). A psychologist who searches introspectively for the 'carriers of relations' between external objects is quite as likely to find kinesthetic sensibles as a policeman searching a colored boarding house is to arrest an afro-american.

ing color differences will keep beads which another, more expert (or the same person after more experience), will unhesitatingly reject. Now this training is not the association of some particular reaction with the colors or the color differences, for the person in question will discriminate just as well between beads *a* and *b* if he is selecting the class in which *a* belongs as if he were rejecting that class.

In all this, I may be whacking at a man of straw; there may be no one who holds to a kinesthetic theory of relation-perception such as I have been discussing. But if some of those who have been talking in a vague way about the motor processes in perception will take me seriously enough to say just what they mean, I will count my time well spent. It is possible that some who talk in terms of kinesthesis are really sensationalists; that they mean that a perceived relation *is* a kinesthetic sensation or a kinesthetic complex. It is clear that Professor Titchener, however, is not promulgating any such crude theory.

§ 6. The Theory of Relational States of Consciousness

This theory was elaborated by Thomas Brown, and was by him given a form very similar to that under which it is now widely known. Spencer and James took it directly over from him, although each of them modified it, for worse or better. Brown was rated by Hamilton as something of a bungler in philosophy, and he has been fairly well neglected for the past fifty years. Perhaps to a certain extent Brown merited the reputation he has received: it was surely stupid of him to erect his theory of 'feelings of relation' on the foundation of thoroughgoing representationism which he laid,[1] for the two are highly incompatible. Nevertheless, the development of this theory alone is sufficient to demonstrate Brown's genius, and to give him an honored place in the history of psychology.[2]

[1] Brown, 'Lectures on the Philosophy of the Human Mind,' XXVII. and XXVIII.

[2] James mentions Destutt (de Tracy), Laromiguière, and Cardaillac as among those who have "explicitly contended for feelings of relation" 'Principles,' I., 248). These philosophers were contemporaries of Brown; and Hamilton accuses Brown of having borrowed largely from Destutt ('Reid's Works,' 868). On this point at least, Brown can hardly be guilty of theft, for Destutt does not seem to have held a theory like that

After examining at some length the theory of relations which he alleges to be Condillac's, Brown states his own theory very clearly. "It is not, therefore, as being susceptible of *mere sensation*, but as being susceptible of *more* than sensation, that the mind is able to compare its sensations with each other. We may see, and certainly do see, objects together, without forming uniformly the same comparison; which could not be the case if the mere coexistence of the two perceptions constituted or involved the comparison itself. In the case of a *horse* and *sheep*, for example, though these, in the sensations which they excite, cannot, at different times, be very different, we compare, at different times, their color, their forms, their magnitudes, their functions, and the uses to which we put them, and we consider them as related in various other ways. The perceptions being the same, the comparisons, or subsequent feelings of relation, are different; and though the relation cannot be felt but when both objects are considered together, it is truly no part of the perception of each." A clear statement, even if erected on false premises. "Innumerable objects may be, and are, continually present to us *at once*, so as to produce one complex affection of mind,—fields, groves, mountains, streams,—but the mere *coexistence of these*, so as to form in our thought one scene, involves no feeling of comparison; and if the mind had not been susceptible of other affections than those of sense, or of mere remembrance of the past objects of sense, either in whole or in part, it might, when such a scene was present, have existed forever in the state which forms the complex perception of the scene, without the slightest notion of the *relation* of its parts to the whole, or to each other.

of Brown (James to the contrary notwithstanding), but rather an ordinary form of representationism. The theory of Laromiguière concerning relations is like that of Brown, but as Brown's 'Lectures' were written in 1810–11, and Laromiguière's 'Leçons de philosophie' were published between 1815 and 1818, there is no evidence of 'borrowing' here. Cardaillac (a pupil of Laromiguière) did not publish his 'Études élémentaires de philosophie' until 1830. The common features of the French and Scottish branches of the school must doubtless be attributed to the common antecedents. In giving credit to Brown, I am not belittling Laromiguière (whose system is in many respects superior to that of Brown), but I am moved by the consideration that the latter had no influence on English psychology, whereas the former has been profoundly influential—too much so.

"When I thus attempt to prove, by so many wearying arguments, that the feeling which constitutes our comparison of our sensations, or in other words, our belief in their agreement or disagreement, is itself a state of mind, different from either of the separate sensations which we compare, and different from both, as merely coexisting, I cannot but feel, what many of you have probably felt already, as if I were laboring to demonstrate a mere truism."[1]

The occurrence of a feeling of relation, Brown calls *judgment*, or *relative suggestion*. He says that comparison, "though it involve the feeling of relation, seems to me also to imply a voluntary seeking for some relation, which is far from necessary to the mere internal suggestion or feeling of relation itself. The *resemblance* of two objects strikes me, indeed, when I am studiously comparing them; but it strikes me also, with not less force, on many other occasions when I had not previously been forming the slightest intentional comparison." "When the feelings of relation seem to us to arise spontaneously, they are not in themselves different from the feelings of relation, that arise, in our intentional comparisons or judgments."

"I perceive, for example, a horse and a sheep at the same moment. The perception of the two is followed by that different state of mind which constitutes the feeling of their agreement in certain respects, or of their disagreement in certain other respects. I think of the square of the hypothenuse of a right-angled triangle, and of the squares of the two other sides;—I feel the relation of equality. I see a dramatic representation; I listen to the cold conceits which the author of the tragedy . . . gives to his hero in his most impassioned situations;—I am instantly struck with their unsuitableness to the character and the circumstances."

Brown devotes seven lectures to the details of 'relative suggestion.'[2] In the first of these lectures he reiterates very pointedly his systematic view of feelings of relation. "The *feelings of relation* are states of the mind essentially different from our simple perceptions, or conceptions of the objects that

[1] Brown, *op. cit.*, Lecture XXXIII.
[2] Lectures XLV–LI.

seem to us related, or from the combinations which we form of these, in the complex groupings of our fancy. . . . There is an original tendency or susceptibility of the mind, by which, on perceiving together different objects, we are instantly, without the intervention of any other mental process, sensible of their relation in certain respects, as truly as there is an original tendency or susceptibility of the mind, by which, when external objects are present, and have produced a certain affection of our sensorial organ, we are instantly affected with the primary elementary feelings of perception; and, I may add, that, as our sensations or perceptions are of various species, so there are various species of *relations;*—the number of relations indeed, even of external things, being almost infinite, while the number of perceptions is, necessarily, limited by that of the objects which have the power of producing some affection of our organs of sensation.

"The more numerous these relations may be, however, the more necessary does some arrangement of them become."

Brown proceeds, accordingly, to arrange relations, classifying them under the two main heads of *relations of coexistence*, and *relations of succession*.

By means of the 'feelings of relation,' Brown solves the problem of universals, and puts conceptualism on a psychological (or pseudopsychological) basis. The universal is simply a relation of resemblance, to which a certain name is given. "The word *animal*, for example, is a general term, expressive of a particular relation of resemblance that is felt by us. *A horse is an animal*, is a *proposition*, which is merely the brief expression of this felt resemblance of a horse to various other creatures, included by us in the general term. It is the same in all the other species of relations which we are capable of feeling." Then, specifying position, degree, proportion, and comprehension: "In all such cases, it is very evident, that the verbal statement of the proposition does not alter the nature of the relative suggestion, or feeling of relation, which it expresses, but simply expresses to others, a relation that must have been felt, before the proposition could be framed."[1]

[1] Brown, *op. cit.*, Lecture XLVIII.

Statements similar to those quoted above from Brown occur over and over in his Lectures. It is clear that he considered the 'feeling of relation' a representative state of the 'mind'; quite on a plane with 'simple perceptions,' but generically distinct from them. The 'perceptions' represent external objects, which act on the 'sensorial organs'; the 'feelings of relation' represent the relations between the objects. Both are 'states of the mind.' Occasionally, Brown smuggles in real relations where he should be speaking of 'feelings of relation,' as in the last quotations above, but on the whole he is as consistent as any representationist.

In addition to the general difficulties in the way of a representative doctrine of relational elements, Brown introduces more, by his claim that the 'feeling of relation' and the 'simple perception' differ in kind. How two modifications of one thing *can* differ in kind, he does not explain. The difference must be nominal, like the 'transformation' of the sensation in the doctrine to which Brown so specifically objects, and to which, after all, his own scheme is somewhat akin.

Brown's philosophy was profoundly influential in Great Britain and in America in the first half of the nineteenth century. Thomas Upham, for example, in his 'Elements of Mental Philosophy,' published eleven years after Brown's 'Lectures,' shows the influence of the latter work explicitly, and follows Brown's treatment of relative 'suggestion,' classifying the relations on a scheme modified very slightly from that of Brown.[1] Abercrombie also adopts Brown's 'relative suggestion,' although not his classification.

§ 7. James's Version of the Theory of Relational States

James's ideas on the perception of relations show clear indications of having been taken from Brown, but they were made more workable in the scheme of James. James maintains that there are 'feelings of relation' as well as 'sensations' but he does not insist so strongly on the difference in the kind of 'mental state'; the 'state' moreover is not that which is

[1] Upham, 'Elements of Mental Philosophy,' Volume I., Division First, Part Second, Chapter IV.; or, *abridged edition*, Part II., Chapter IV.

known, but is the knower. James is primarily a realist, and falls back on a kind of secondary representationism only to account for memory and introspection. The 'state of consciousness' knows an external reality[1] and knows its own bare existence,[2] and these are direct experiences; but when the external reality is no longer present, the 'state' which knew that reality is known by the 'state's' successor, and by virtue of the first 'state's' having previously known the object, it represents the object now when it itself is known.[3]

Some of the 'states' know the qualities of objects, and others (or else the same 'states') know relations. "*So surely as relations between objects exist in rerum naturâ, so surely, and more surely, do feelings exist to which these relations are known.*" "If we speak objectively, it is the real relations that appear revealed; if we speak subjectively, it is the stream of consciousness that matches each of them by an inward coloring of its own. In either case the relations are numberless, and no existing language is capable of doing justice to all their shades."[4]

The feelings here spoken of are 'substantive states,' or rather, the 'substantive state' may be analytically considered as if it included 'feelings of relation' and sensations; actually, it is a simple 'state' which is aware of a complex object involving relations: for James quotes with approval Brown's remark on the mistake "Of supposing that the most complex states of mind are not truly, in their very essence, as much one and indivisible as those which we term simple,"[5] and on the next page says that "*There is no manifold of coexisting ideas;* the notion of such a thing is a chimera. Whatever things are thought in relation are thought from the outset in a unity, in a single pulse of subjectivity, a single psychosis, feeling, or state of mind." Later, he says: "We, on the contrary, put the Multiplicity with the Reality[6] outside, and leave the mind sim-

[1] James, 'Principles of Psychology,' I., 216–220; II., 3–6.
[2] *Op. cit.*, I., 341.
[3] *Op. cit.*, I., 336–342.
[4] *Op. cit.*, I., 245.
[5] *Op. cit.*, I., 277.
[6] *Op. cit.*, I., 363.

ple." The 'feelings of relation' so far described are therefore on the plane of sensations in at least one important respect: neither really exists, but the 'feeling of relation' is the limit which the 'state' approaches as the sensible qualities in the object known become fewer, and the 'sensation' is the limit as the relations in the object become fewer. This is made more certain in the explanation of the connection between sensation and perception, where we are told that "pure sensation" is the state cognizing a "simple quality apprehended irrelatively to other things" and that "the fuller of relations the object is, . . . the more unreservedly do we call the state of mind a perception."[1]

Although James's doctrine of perception is based on the theory of immediately perceived relations, in the chapter on Space he is somewhat confusing. While admitting that "Most 'relations' are feelings of an entirely different order from the terms they relate" he insists that "*In the field of space the relations are facts of the same order with the facts they relate.*"[2] In a footnote, however, he crosses his trail by admitting that "All that we have meant by speaking of up and down, right and left, as *sensations*" is expressed by saying with Kant that they are matters of 'immediate intuition.'[3]

Not only in this case, but in others, there are inconsistencies in James's 'Principles,' which are readily explained. The various portions of the work were written at different times, and not in chapter order, and hence the terminology and the mode of expression vary. Perhaps James's theories varied too, slightly. It may be that when he wrote the chapter on the Perception of Things, for example, he was inclined towards ordinary representationism; but we are not warranted in assuming this by the lapses into representative phraseology.

I have said that according to James, certain relational 'states' are 'substantive.' This is not in accord with the ordinary interpretation of James's theory, but has the virtue of being more in accordance with what James says than is the

[1] *Op. cit.*, II., 1.
[2] *Op. cit.*, II., 149.
[3] *Op. cit.*, II., 151, footnote.

opposed view, which assumes that the 'feelings of relation' are identical with 'transitive states.'[1]

It is manifestly impossible that the relations which are known with the related objects in 'one unitary pulse of thought' should be known by a 'transitive state,' while the said objects are known by a 'substantive state,' for the same 'state' can not be both 'transitive' and 'substantive'; neither can it be said that the difference between a 'transitive state' and a 'substantive state' is a mere analytical fiction. The distinction is real, and the two are separated in time, as well as distinguished by difference in rate of change. Clearly the 'feelings of relation' are not all 'transitive states': and James explicitly says they are not. Discussing the relation theory of Spencer, he says: "His philosophy is crude in that he seems to suppose that it is only in transitive states that outward relations are known; whereas in truth space relations, relations of contrast, etc., are felt along with their terms, in substantive states as well as in transitive states, as we shall abundantly see."[2] This statement is as plain as could be, and as it was apparently written after the main part of the chapter with which it occurs, there is no doubt that James meant it; and the principle involved in it is fairly well adhered to throughout the book.

What are the 'transitive' relational 'states' in James's system? Their significance is made clear by the consideration of the nature of the 'states of consciousness.' In the analogy of the kaleidoscope[3] James is nominally describing the brain process, but really has in mind the 'psychosis,' as is shown by his skip from the 'lingering' brain process to the 'lingering consciousness.' The stream of consciousness here, as in the whole chapter, is supposed to be something (really mind-stuff

[1] Woodworth is one of the few who have written concerning James's theory and have not overlooked the substantive relational states. See "The Consciousness of Relation" in the volume of essays in honor of Professor James by members of the Columbia Faculty, 485–507. Woodworth holds to the main points of James's theory, but extends it to affirm the perception of bare relations;—of relations without any terms related; and also holds that all qualities may be resolved into relations.

[2] *Op. cit.*, I., 248–249, footnote. It is rather odd that Calkins ('Introduction to Psychology,' 134) should accuse James of the very thing for which James condemned Spencer.

[3] *Op. cit.*, I., 246.

of some sort) which is in constant change; but there are moments in which the change is relatively slight, separated by moments in which it is large, like the successive rearrangements of a kaleidoscope which is slowly rotated. The 'relatively stable states of consciousness' are perceptive of objects (including sensible qualities and relations); but if these 'states' are cognitive, the intervening 'states' (for they certainly are 'states') must also be cognitive. Cognitive of what? On this point the theory is not absolutely clear, but it seems to be that the cognition *may* be of some relation between the two things cognized by the temporally adjacent 'substantive states,' although the cognition is certainly in some cases cognition of the transition from the one object to the other. It seems almost as if James meant by 'transitive states' the 'relations of succession' of Brown. The 'feeling of tendency' is apparently a 'transitive state' in which the importance of the 'state' *from* which is slight and the importance of the 'state' *to* which is large.

I may illustrate the difference between the 'substantive' and 'transitive' 'feelings of relation' by the cognition of bread-and-butter in the first place, and the cognition of bread followed by the cognition of butter in the second place. I may be aware of the bread and the butter as a complex object; that is, my 'state' at a given moment may be aware of the bread, of the butter, and the relation of the one to the other. Or, I may be aware of the bread, and then aware of the butter; the transition from the one 'state' to the other *may* be the 'feeling of *and*,' as when I am taking stock of the different articles on the table before me. These two complexes, bread-and-butter on the one hand, and bread *and* butter on the other, are essentially different; one involves Brown's 'relation of coexistence,' and the other a 'relation of succession.'

The 'state' cognizing bread may however be separated from (or connected with, *comme il vous plaira*) the 'state' cognizing butter, by a 'feeling of *but*,' as when I expected or desired some bread without butter, and find it spread. In this case, the 'state' does not cognize merely a relation existing *in rerum naturâ* between the bread and the butter (if indeed the 'feeling

of *and*' did), but a very complex relation between the bread-and-butter and the bread-*sans*-butter cognized by a preceding 'state' (imaginatively). We might indeed question whether the 'states' under discussion should not really be given the greater part of their individuality through the emotional contents they cognize; but this is like asserting that an author ought to have made a character to be otherwise than as it is actually delineated.

We have noticed the fact that the 'substantive' 'feelings of relation' are as unreal as 'sensations'; the transitive 'feelings of relation' on the contrary are as real (in the mechanical scheme, that is) as the actual 'substantive states.' No wonder that the 'transitive' 'feelings of relation' are the ones which had the main interest for James, so that we are in danger of forgetting his other variety.

If James's theory of the *observing* 'mental state' is clever, his theory of the *observed* 'mental state' is a marvel of ingenuity. The 'mental state' observed (in memory) represents, as we have said, the objects (including relations) which it previously knew; but, in the passage from subjectivity to objectivity the 'transitive states' disappear, and only a series of 'substantive states' is left for scrutiny.[1]

By the ingenious device of the disappearing 'transitive state' James makes his machine go, whereas Brown's contrivance, lacking this device, breaks down. James does not attempt to make an objectified mental modification function as a relation between two other mental modifications. In his representative system he has only the 'states' standing for the relatively distinct objects; and presumably the new 'state' which knows these is also aware of the relations between them (not mental modifications, but real relations between mental modifications), and these relations may therefore represent the relations between the objects represented by the 'states.'

Two points are left unexplained, it is true. The analysis in memory of the unitary 'substantive states,' which are in actuality neither 'feelings of relation' nor 'sensations,' ought

[1] See my discussion of 'The Case against Introspection,' PSYCHOL. REVIEW, 1912, XXI., pp. 408–409.

in conformity with the doctrine in regard to the 'transitive states' to show no 'feelings of relation,' but only 'sensations.' But whether this is the solution James intended, or whether he would have said that after all the analysis is not of the 'state' but of the object represented thereby, we can not say. The second point is how any 'state,' even the most 'substantive' can survive in memory at all, since really none of them endure, but are at every moment in change, the difference between the 'substantive' and the 'transitive' being only a matter of degree, not of kind. But such minor criticisms have really no point at this date. It is a fine old model of a 'mind' that James constructed, and the fact that nothing like it has ever been discovered on the earth or in the heavens above the earth or in the waters that are under the earth ought not to prevent our giving due admiration to the nice adjustment of its wheels and levers.

The theory as I have explained it is the one presented by James in his *magnum opus*. In his later writings, after he rejected not only the 'feelings of relation' but the whole camorra of 'feelings,' he still contended for the reality of the cognized relations, dealing mostly with the relations corresponding to the 'transitive states,' and talking in terms of 'experiences.'[1] 'Consciousness' is abandoned, and the function of cognition is carried on between 'experiences'; one 'experience' knows another and is known by a third. Just what these 'experiences' are, James does not explain, but the term does not have either of the significations which it has in the 'Principles,' and I can find no definite meaning which will apply.[2] Probably it is merely one of the pawns in the meta-

[1] 'The Thing and its Relations,' *Journal of Philosophy, etc.*, 1905, Vol. II., 29–41; 'A World of Pure Experience,' *Journal of Philosophy, etc.*, 1904, I., 522–543, 561–570; 'Does Consciousness Exist?' *Journal of Philosophy, etc.*, 1904, Vol. I., 477–491; 'The Meaning of Truth,' 1909.

[2] These 'experiences' are not actual experiences of objects, as the term is legitimately used; they are not cognitions, for they cognize one another, and no other objects for them to cognize are provided; to speak of one cognition cognizing another reminds one of the old story of the people who lived by taking in one another's washing. To suppose that the 'experiences' are objects cognized, reduces the situation at my breakfast table to the coffee-pot experiencing the toast, and the toast experiencing the butter, and the butter experiencing a feeling of satisfaction; which renders it rather

physical game which James was playing in his latter years. The only certain point in James's last works is that he knew that the details into which he had worked out his radical empiricism were wrong, but that the direction in which he was working was right. This is more than it is given to many philosophers to know, and we could not expect that in his last years he would be able to rebuild his system with his former precision.

A theory of relation-perception which is possibly somewhat like that of James has been propounded by Professor Calkins. At least, as stated in her first text-book,[1] it seems to be like James's theory. But in her second psychological text[2] the situation is rendered doubtful by her ascription of theories similar to hers to Ebbinghaus and Münsterberg, who are not generally understood as favoring James's theory. Another source of difficulty in the interpretation of Professor Calkins's doctrine of 'relational elements' is in her peculiar use of the term 'elements.' Intensity and extensity, for example, are in her system not points with regard to which elements may differ, but are themselves elements. Extensity is "an entirely peculiar kind of feeling."[3] Moreover, while the 'consciousness' which Miss Calkins discusses may be something like that which James invented and subsequently discarded,—there is at least an indication in the early part of the First Book that it 'knows' something extra-mental,—the author is constantly reverting to a different usage, as when she 'concentrates' her 'consciousness' on the boat,[4] and even to the commoner usage, in which 'consciousness' or 'experiences' are considered as if they were the objects seen, smelled, etc.[5]

needless for me to attend the function at all. Some realists may have such a scheme as this to propose, but as James was blest with a sense of humor it is not fair to assume that he was preaching this doctrine.

[1] Calkins, 'Introduction to Psychology,' Chapter X.

[2] Calkins, 'First Book of Psychology,' Chapter VIII., II., and Appendix,'§ VIII., II.

[3] Calkins, 'First Book,' Chapter III., I., *a*, 3.

[4] Calkins, *op. cit.*, Chapter VI., I.

[5] Calkins, *op. cit.*, Chapter III.

§ 8. The Consideration of Relations as Elements of Content

If we give up the attempt to stage the experienced world as a drama of 'mental modifications,' 'mental processes,' 'states of consciousness,' or any other marionettes of the theater called the 'mind,' and try to find, by observation, what it is that we observe, and into what elements or factors it may be by observation resolved, and how the elements or quasi-elements and the complexes or quasi-complexes behave, we may make some progress. We find sensibles (sentienda) and we find that these are not absolutely simple, even in our analysis, but that they differ from one another, or vary in condition, in several specific ways. If we compare two sensibles such as red and green, we notice a difference in *quality;* and the comparing, in this case, is nothing but the noticing of the difference. If we compare two sweets,[1] we may notice another difference, the difference in *intensity*. When we talk abstractly about the elementary sensibles, we speak of the fact that they may differ in these characteristic ways by ascribing to them *characters* of quality and intensity. We can not conceive of a sensible which has not these two characters (as well as certain others); that is to say, we can not conceive of a sensible which does not involve these two (and certain other) relations. By this, in the last resort, we mean no more than that we never observe sensibles which are not found involved with these relations, if the observation has been thorough.

If on the other hand we 'attend to' the relations, we find them always involved with sensibles. No difference is perceived, except a specific difference; by specific differences we mean differences which are ultimately differences of definite sensibles. We may, of course, have differences of differences; we may have differences of other relations; relation of all sorts, in short, may be related; but the differences which differ reduce finally to differences of sensibles, and all other relations of relations rest, even if at several removes, on a sensible foundation.[2]

[1] Assuming that there are two sweets possible. If not, the wording of the statement needs a slight change.

[2] I do not mean to say that the relations are *internal;* on the contrary, I am con-

Admitting feelables (as pleasure, pain) without argument, we have three sorts of elements out of which the known reality may be considered as made: relations, sensibles, and feelables. These are all that we observe; we do not observe observing or observation; hence we can not say that the observing of one of these three classes (that is, the consciousness of one of them) differs from the observing of either of the others; we can not say, therefore, that there is any difference between sensation and feeling, or between either and the consciousness of relation. We are not supposing any different kinds of consciousness, but only different kinds of things of which we are conscious. And of these, even, we are not conscious separately, but are conscious of complexes in which all three coexist; or rather, we may resolve the perceived objects into these elements, if the two statements really mean different things.

The first English writer to state the general result of this analysis, so far as I know, and possibly the first to state it in any language, was Berkeley. The statement was not embodied in the bishop's earlier writings, nor indeed in the first edition of any of his writings, but was added to the second edition of his 'Principles' in 1734, after his works had all been published. It represents therefore, without doubt, his mature and final view. It is hardly ever mentioned by critics and expositors, although it puts a new face on his system; but as Fraser has reminded us, those who have commented on Berkeley have rarely thought it necessary to read him carefully first.

"We know, and have a notion of relations between things and ideas—which relations are distinct from the ideas or things related inasmuch as the latter may be perceived by us without our perceiving the former. To me, it seems that ideas, spirits, and relations are all in their respective kinds the objects of human knowledge and discourse; and that the term idea would be improperly extended to signify everything we know or have a knowledge of."[1]

vinced that they are *external*, although I lay no stress on this point at present as it does not seem essential to the establishment of the reality of perceived relations. See Russel, 'Philosophical Essays,' 160–169; or 'The Nature of Truth,' *Proceedings of the Aristotelian Society*, 1906–7: also James, 'The Thing and its Relations,' *Journal of Philosophy, etc.*, II., 36–38.

[1] Berkeley, 'On the Principles of Human Knowledge,' 2d edition, § 89. See also § 12 and § 142.

In Berkeley's terminology, of course, the 'idea' is not the consciousness of anything, but anything not included in the categories of relations and spirits, of which one is or may be conscious. An 'idea' is spoken of by Berkeley as being 'in the mind,' but by that phrase, as he carefully explained, he meant no more than that the 'idea' was perceived. The 'mind' with which psychology has had so much alleged dealing in the last hundred years, Berkeley tried to abolish altogether. Far from holding that the world is 'subjective'; that the senses deceive us; or that the physical world is unreal; as is even now said of Berkeley; he held to the immediate perception of an objective world. In this world, relations are perceived as much as are sensibles. It is true that the 'ideas' of Berkeley really include relational elements; but although he did not carry his analysis down to the bottom, he recognized the nature of its results.

The main features of the consideration of relations as elements of content—what I should prefer to call the empirical theory of relations, if it may logically be called a theory—may be stated categorically under three heads.

1. Real relations of real objects are really perceived. The perceived world is real, and not a phantasm or species of some unperceived world. As the brown color of the table on which I write is a real color of a real table, so the difference I notice between the brown of the table-top and the black of the ink in the well, is a real difference.

2. The elementary things perceived—sensibles, relations, and feelables—are not parts or functions of the perceiving ego, any more than they are 'states of consciousness' by which something else is perceived. To say that these objects are 'mental' can mean only one of two things: (1) that the objects are perceived or may be perceived; or (2) that the Protean term *mental* is used to cover the whole universe. In the latter case, the distinction between the perceiving and the perceived remains the same, although both are called 'mental,' as if one were called 'mental' and the other 'non-mental.' But, if when we have defined experienced things, as 'mental,' we neglect the fact that we have extended the term, and proceed to treat the

objects as if they were 'mental' in the restricted signification, we plunge our psychology into grievous confusion. Better and simpler to abolish the terms 'mental' and 'psychical' for all scientific purposes.

3. The consciousness of one object does not differ in kind, so far as we know, from the consciousness of another object. The only differences (aside from a possible difference of degree or vividness) are in the objects of consciousness. Of differences in consciousness corresponding to the three kinds of elements of content we have absolutely no evidence.

4. Neither sensibles nor feelables nor relations, it is probable, are ever perceived alone. It can not be said with confidence that such perception is impossible, but in ordinary cases the consciousness is of an object which involves two and probably all three of these elements; or, the object may be analytically resolved into these.

From these statements it is clear that I am not advocating a theory of 'relational elements of consciousness,' and that I am not concerned with the question whether 'bare' relations are perceived. It is also clear, I hope, that I am willing to join in the spirit of the common saying (as voiced by James and Brown) that consciousness is *simple*, however much I may take issue with the mechanical schemes on which this simplicity has been interpreted. However complex the object may be, there is no possibility of analyzing the consciousness thereof. Hence, there is no discernible difference between the consciousness of one element in the object and the consciousness of another element.

It should also be clear that this empirical view of relations is developed on a basis which makes 'introspection' in the traditional sense impossible. This is a perfectly satisfactory basis, as there is no evidence that any one was able at any time to 'introspect.' Certainly the present writer is able to do it not one whit more than he can send out 'soul vibrations.'

In affirming relations to be elements of content, we are not complicating the current psychological scheme by adding something to it, but are really simplifying by eliminating superfluities. Current opposition to 'relational elements' seems to

be directed altogether at the theory of Brown, which I have admitted to be an impossible addition to representationism. We are not trying to add 'relational states' to 'sensational states,' but are subtracting the 'sensational states.' None of the 'states,' 'modifications' or 'processes' of the 'mind' are discoverable, and we would do well to discard the misleading labels. The only 'relations' we affirm are the actual ones, of which, I suppose, no one really has ever doubted. The things related are the feelables, and the sensible qualities (to use James's term) of real objects.

Certain modern philosophers, interested in the problem of knowledge from a non-psychological point of view, are in the habit of calling consciousness a relation: either the relation of subject and object, or (now that subjects are out of fashion) a peculiar relation of objects to one another.[1] This seems to raise a difficulty, for if consciousness can be asserted to be a relation, comparable in any way to other relations, then it is knowable. The difficulty, however, is an entirely arbitrary one. In the game of metaphysics, where each term is given its definite value and then played according to the fixed rules of logic, it is quite legitimate to define consciousness as a relation, or as an activity, or as a lamp-post; and then, if the definition is not forgotten in the heat of the game (as sometimes happens), the terms may be carried through with perfect consistency. In psychology, however, we are restricted by the rule that we must attempt to describe and analyse things as they seem really to be; and the consciousness of which we are speaking here is not comparable to difference, or to any other relation, any more than it is comparable to activity. Relations, activities, and lamp-posts are things which are known; and consciousness (as the term is here used) is the knowing which is

[1] Many writers use the term 'relation' to designate consciousness, but it is possible that some of them merely do so in default of a more suitable term, and would not strictly hold to the position to which the usage seems to commit them. Among those who are perfectly explicit on this point however are some of the most brilliant of living philosophers, whose opinions it seems presumptuous for me to challenge. For example: Professor Alexander, 'On Relations; and in Particular the Cognitive Relation,' 1912, *Mind*, N. S., XXI., 305–328. Professor Woodbridge, 'The Nature of Consciousness,' *Journal of Philosophy, etc.*, II., 119–12 and 'Consciousness, the Sense Organ and the Nervous System,' same *Journal*, VI., 449–455.

involved in that statement. If one defines consciousness as a relation (or a lamp-post), he thereby sacrifices a useful term needlessly, and continues to assume the same old consciousness, for which he needs a new name, in addition to the relation (or lamp-post), which he calls by the old name.

In conclusion, I wish to register the admission that neither the existence nor the perception of relations as perceived facts can not be proved in a strictly experimental way. Neither can the existence or perception of sensibles. You can no more prove that the difference between red and green is perceived by any one, than you can prove that green is perceived. These things are fundamental postulates, justifiable only by observation, on which psychological theory and experimentation are based. Assume the representative postulates, and you build a system of psychology which furnishes specific problems for experimental solution; but the interpretation of the experimental results is in terms of your postulates. Reject your postulates, and a great deal of what was supposed to be experimental results goes with them.

With the recognition of relations as real, a real psychology of perception and thought seems possible. So far we have contented ourselves (in spite of the efforts of the Würtzburgers) with a mere psychology of sensibles, because we have assumed that relations were indispensable tools which we might work with, but which we should not presume to work upon.

CLASSIFICATIONS OF PERCEIVED RELATIONS.

The "connexions of and agreement, or disagreement or repugnancy" of ideas according to LOCKE:

I. Identity, or diversity.
II. Relation.
III. Coexistence, or necessary succession.
IV. Real Existence.

The "kinds of relations" according to HUME:

1. Resemblance.
2. Identity.
3. Space and time.
4. Quantity or number.
5. Degree of quality.
6. Contrariety
7. Cause and effect.

Difference, according to Hume, is a "negation of relation."

The "feelings of relation," "relative suggestions," or "relations either of external objects or of the feelings of the mind" according to BROWN:

I. Of coexistence.
   1. Position.
   2. Resemblance or difference.
   3. Degree.
   4. Proportion.
   5. Comprehensiveness. [Whole and part.]

II. Of succession.
   1. Casual.
   2. Invariable. [Cause and effect.]

The "relations of things, whether referring to external events or mental processes" according to ABERCROMBIE:

1. Character.
2. Resemblance and analogy.
3. Accordance. [Inductive.]
4. Composition.
5. Causation.
6. Degree and proportion.
7. Moral relations.

The "classes of relations" according to UPHAM:

I. Identity and diversity.
II. Degree.
III. Proportion.
IV. Place or position.
V. Time.
VI. Possession.
VII. Cause and effect.

According to SPENCER, the "feelings of relation" are strictly *changes in consciousness*. Spencer distinguishes between *relations of succession* and *relations of coexistence*, but fundamentally all feelings of relation are relations of *succession*. The feeling of *coexistence* is a double change, between exactly the same terms in each case but in opposite directions. A single change, from one term to another, is the relation of *unlikeness* or *difference*, which is therefore the fundamental relation-feeling. *Likeness*, or *non-difference* is a double change between two terms, from the first to the second and back to the first, the two differences cancelling. Spencer does not explain how this differs from mere coexistence; perhaps he intended to identify it with likeness, or to include it in the latter.

There are two classes of differences: differences of *degree* and differences of *kind*. Finally, all relations of succession (which seems to mean *all* relations) are divided into the *fortuitous*, the *probable*, and the *necessary*.

Spencer, 'Principles of Psychology,' Vol. I., Ch. II., § 67; Vol. II., Chs. XIX.–XXIV.

THE EFFECT OF LENGTH OF SERIES UPON RECOGNITION MEMORY[1]

BY EDWARD K. STRONG, JR.

Much work has been done in studying the effect of length of series upon recall memory. The results differ considerably in different investigations but they all go to show that as the length of the series increases there is a much greater corresponding increase in the time or energy necessary for its mastery. The purpose of this paper is to present the results obtained in a corresponding study in which, however, *recognition* memory was employed. The results so obtained indicate that the number in the series of stimuli affects the results almost in direct proportion to the increase. That is, as the number of stimuli is increased the per cent. that can be recognized decreases.[2]

Recognition memory refers in this connection to the process of recognizing or identifying an object as having been seen before in some particular connection. No reason for the identification need be present,—all that is necessary is that the individual is certain that this is the object which he encountered before. The difference between *recognition* and *recall* memory is then that the former requires simple identification of the object when it is presented a second time while the latter requires a reproduction of the object without any external aid whatever.

The Experiment

The experiment was as follows. Six series of advertisements were used consisting of 5, 10, 25, 50, 100, and 150 advertisements each.[3] The advertisements were exposed at a

[1] From the Columbia University Psychological Laboratory.

[2] As will be shown later this generalization is not quite true, but it is exact enough for a general statement.

[3] As different advertisements have very different attention-value two series of 5 advertisements were actually employed so as to minimize the effect of the particular

uniform rate of one per second. Immediately after the advertisements in any series had been presented a second set containing those advertisements and an equal number of other advertisements was given the subject. He was then instructed to pick out those advertisements from the second set which he recognized as having been just previously shown him. The subject was further instructed to sort this second set into four piles. In the first pile he was to put only those advertisements he was *absolutely* sure he had just seen (100 per cent. sure); in the second pile he was to put those advertisements he was *reasonably* sure he had just seen but of which he was not absolutely sure (about 75 per cent. sure); in the third pile, those advertisements which he had a faint idea he had seen but of which he was not at all sure (about 25 per cent. sure). The remainder of the advertisements,—those he did not remember seeing,—were to be put in the fourth pile. In this way the subject sorted the advertisements into three piles representing respectively 100 per cent., 75 per cent., and 25 per cent. surety, and into a fourth which represented rather lack of memory about its contents than positive knowledge that they had not been presented before.

The advertisements used in these series were all full-page advertisements and were all different except that the advertisements in the series of 150 comprised the advertisements in the series of 100 and of 50 advertisements. But no subject that was used in the study of the series of 150 advertisements was used with the series of 100 or 50 advertisements. In this way no advertisement was repeated for any subject. Extreme care was exercised also that no two advertisements advertising the same commodity and the same firm should be used. It was impossible to obtain enough advertisements so that no firm should be duplicated. But, as already stated, if two or more advertisements of the same firm were used it was seen to that they were of widely different commodities, such as the General Electric lamp and the General Electric flatiron. Unfortunately, after

advertisements used in these very short series. The results, however, of the two series of 5 advertisements each were almost exactly identical. They are therefore combined into one result and reported as such throughout the paper.

the experiment had been carried on for some time, it was discovered that there were four or five advertisements of the same commodity and firm in the several series. A careful watch was made of the effect of these advertisements. They were mistakenly identified to a greater extent than the others but the effect on the totals given below is less than one half per cent.

Each series of advertisements was presented to 20 men and 20 women. All the subjects were students at Columbia University, and were all within a few years of each other in age. The same subject was shown not more than 4 series, so that the results are not obtained from 40 different subjects, but from a considerably larger number.

TABLE I

TOTAL NUMBER AND PERCENTAGE OF CORRECT RECOGNITIONS FOR EACH OF THE SIX SERIES

Subjects	No. of Ads	Total Number			Percentage				
		Pile No. 1.	Pile No. 2	Pile No. 3	Pile No. 1	Pile No. 2	Pile No. 3	Summary	P. E.
80	5	4.11	.23	.11	82.3	4.5	2.3	86.2	*1.4*
40	10	8.15	.45	.25	81.5	4.5	2.5	85.0	*1.3*
40	25	18.23	1.20	1.15	72.9	4.8	4.6	77.6	*1.8*
40	50	30.80	3.00	2.50	61.6	6.0	5.0	67.4	*2.0*
40	100	56.40	6.60	4.80	56.4	6.6	4.8	62.6	*2.2*
40	150	60.60	10.50	6.90	40.4	7.0	5.6	46.8	*1.7*

THE RESULTS

1. *Correct Recognitions.*—Table I. presents the data concerned with the correct recognitions. The first column states the number of subjects,—in each case half were men and half were women. The second column gives the number of advertisements presented in the series. The next three columns give the average number of advertisements which were correctly recognized in piles No. 1, No. 2, and No. 3, respectively. The next three columns give the same results but in terms of per cent. of the total number of advertisements presented. In other words, the first row of this table states that there were 80 subjects employed, that 5 advertisements were presented in the series, and that 4.11 of these were correctly recognized

by placing them in pile No. 1, .23 in pile No. 2, and .11 in pile No. 3. Putting these figures into per cent. we have 82.3 per cent. of the 5 advertisements placed in pile No. 1, 4.5 per cent. in pile No. 2, and 2.3 per cent. in pile No. 3. The score in the "summary" column was computed in the following manner. As pile No. 2 represented 75 per cent. certainty (not 100 per cent. certainty as in pile No. 1) only three fourths of the score in that column is credited toward the summary. Similarly, only one fourth of the score in the column under pile No. 3 is credited toward the summary, because here there was only 25 per cent. certainty in the minds of the subjects when they placed an advertisement in the pile. The summary column thus comprises the amount under pile No. 1, three fourths under pile No. 2, and one fourth under pile No. 3. There may be some objection to this procedure but it is manifestly fairer than to credit the results in the last two piles with full credit. All the subjects understood the scoring and sorted the advertisements on that basis. Preliminary experiments indicated very clearly that advertisements were recognized with varying degrees of certainty and that unless the subject clearly understood that his results would be credited on a sliding scale he would not pick out any but those of which he was absolutely sure.

A survey of the total percentages indicates very clearly that there was a steady decrease in the number of advertisements that could be recognized as the length of the series increased. (This decrease is shown more plainly in Plate I., where the data are plotted.) This per cent. decreased from 86 per cent. with 5 advertisements to 47 per cent. with 150 advertisements. The percentages from the three piles indicate that there was an even more pronounced decrease in those advertisements which are recognized with absolute certainty as the length of the series increases but that there was an opposite tendency in the second and third piles. Here there is a gain of from 2 per cent. to 3 per cent. in each pile as we proceed from series of 5 advertisements to series of 150 advertisements. But the amounts under these two piles are after all only a small portion of the total amount. It is evident,

then, that ordinarily we either recognize an object or we don't recognize it,—that recognition of 150 advertisements just seen from among 300 is little concerned with "maybes" and "perhapses." But it is also evident, that as the difficulty of the

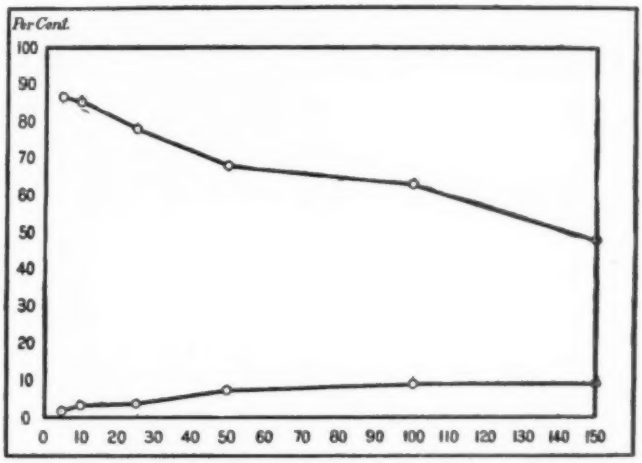

PLATE I. Showing (1) the Decrease in the Per cent. of Correct Recognitions and (2) the Increase in the Per cent. of Incorrect Recognitions as the length of the Series is increased.

task increases we have proportionately less and less certain recognitions.

2. *Incorrect Recognitions.*—But not all the recognitions that are made are correct ones. Some advertisements are identified as having just been seen that actually were not present at all. These facts are presented in Table II. and plotted in Plate I.

TABLE II

TOTAL NUMBER AND PERCENTAGE OF INCORRECT RECOGNITIONS FOR EACH OF THE SIX SERIES

Subjects	No. of Ads.	Total Number			Percentage				
		Pile No. 1	Pile No. 2	Pile No. 3	Pile No. 1	Pile No. 2	Pile No. 3	Summary	P. E.
80	5	.04	.03	.11	.8	.5	2.3	1.7	.3
40	10	.10	.13	.40	1.0	1.3	4.0	2.9	.5
40	25	.30	.28	1.28	1.2	1.1	5.1	3.3	.6
40	50	1.70	1.58	2.40	3.4	3.2	4.8	7.0	.7
40	100	4.53	3.58	5.40	4.5	3.6	5.4	8.6	.8
40	150	5.68	6.88	6.75	3.8	4.6	4.5	8.3	.7

A study of the total amounts or the percentages shows clearly that there was a slightly greater tendency to recognize falsely in the third pile than in the other two piles. This tendency to pick out wrong advertisements also increased with the increase in the length of the series. Indeed, the tendencyto recognize falsely seems to increase approximately as the length of the series increases. But the surprising thing, after all, is that such a very small per cent. of wrong recognitions should be made, that, for example, when 40 per cent. of 150 advertisements are picked out correctly in the first pile only 4 per cent. of the new and incorrect advertisements should be identified as having been seen before. Increasing difficulty of the task results then in decided decrease of recognitions but it does not cause much of an increase in incorrect recognitions. Ability to know then that we haven't seen seems to be more strongly fixed than ability to pick out what we have seen.

3. *The Validity of the Recognitions.*[1]—It is interesting to note now just how accurate the recognitions were. When a subject put one advertisement in the first pile, another in the second, and another in the third, did he approximate at all closely to the designated percentages of 100 per cent., 75 per cent., and 25 per cent. certainty? Table III. and Plate II. supply us

TABLE III

ACCURACY OF THE JUDGMENTS FOR EACH OF THE PILES OF THE SIX SERIES. ALSO THE ACCURACY OF EACH PILE FOR EACH SERIES IS SHOWN IN TERMS OF RATIOS OF THE ACCURACY OF PILE NO. 1

Subjects	No. of Ads.	Per Cent. Correct			Ratios in Terms of Pile No. 1		
		Pile No. 1	Pile No. 2	Pile No. 3	Pile No. 1	Pile No. 2	Pile No. 3
80	5	99.1	90.0	50.0	100	91	50
40	10	98.8	78.3	38.4	100	79	39
40	25	98.4	81.4	47.4	100	83	48
40	50	94.8	65.6	51.0	100	69	54
40	100	92.6	64.9	47.1	100	70	51
40	150	91.4	60.4	50.6	100	66	55

with this information. We have there expressed the per cent. of advertisements which were correctly recognized in the three piles. That is, 99.1 per cent. of all the advertisements placed

[1] Validity of recognitions equals (number of correct recognitions)/(number of correct + incorrect recognitions).

in pile No. 1 in the experiment with a set of 5 advertisements had actually been shown previously while 0.9 per cent. had not been shown. We find here a very slow but steady decrease in the accuracy of the judgments as the length of the series

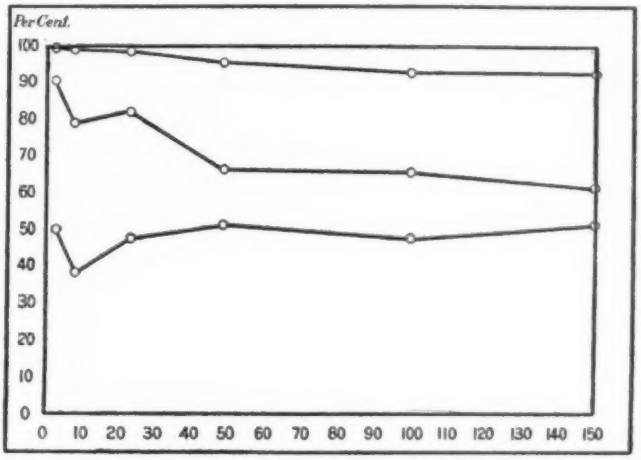

PLATE II. Showing the Relationship between length of Series and the Accuracy of the Recognitions for the three Grades of Certainty.

is increased, a decrease from 99.1 per cent. with 5 advertisements to 91.4 per cent. with 150 advertisements. Likewise we find a steady decrease in the accuracy of the recognitions in pile No. 2. But here the decrease is much more rapid as the series is lengthened, a decrease from 89.9 per cent. correct recognitions with 5 advertisements to 60.4 per cent. with 150 advertisements. On the other hand, the validity of the recognitions in pile No. 3 is not affected by the length of the series, as far as can be determined from this experiment. Here the percentage of right recognitions remains approximately 50 per cent. Pile No. 3 was meant to be used when the recognition seemed but slightly better than a guess, or one correct in four (25 per cent.). Under the conditions of this particular experiment, where we have an equal number of right and wrong advertisements from which to select, a pure guess will be, of course, 50 per cent. of the time correct. That the recognitions in pile No. 3 approximate 50 per cent. means simply that they are no better than random selections.

TABLE IV

THE VALIDITY OF THE RECOGNITIONS FOR EACH PILE SHOWN BY THE DISTRIBUTION OF THE INDIVIDUAL RECORDS

	No. of Ads.	Percentages																				Total No. of Subjects	Median Position
		100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5 0		
Pile No. 1.	5	39						1														40	99.9
	10	36		4																		40	99.7
	25	33	4	3																		40	99.5
	50	15	18	4	2	1																40	96.1
	100	13	12	8	5	1																40	94.6
	150	10	10	10	5	4	1															40	92.5
Pile No. 2.	5	6			1																1	8	99.2
	10	10										3			1							14	99.0
	25	19						1				1							1		2	24	99.3
	50	12		2	2	1		3			2	2	2				1				5	32	82.5
	100	5	1	1	1	1	7	3	3	1	3	1		1	3	1					2	34	70.8
	150	4		3	3	1	3	5	3	2	6		3	1	2	1						37	68.0
Pile No. 3.	5	3										1									3	7	50.0
	10	5										2			2						4	13	48.8
	25	2					1	1				4	1		3	1	1	1			4	19	36.7
	50	4		1	1		2		1	1	3	5	1	1	3	1	1	1			1	27	52.0
	100	2		1		2	2	5		1	1	6	3	3	2			1	1			30	51.7
	150	5			1		1	5	1	3		5	3	3	4	2	1				1	35	51.0

The validity of the recognitions is set forth in another manner in Table IV. Here the individual subjects are considered. The table presents the distribution of the 40 subjects according to the accuracy of their recognitions. To the right of these is given the number of subjects and then the median position of the group. In this way one can grasp much more easily the slow but steady increase of mistaken recognitions in the first pile. This increase is not so easily seen in the results of the other two piles. This is due to the fact that there was a great difference in the number of individuals using these piles. The greater the length of the series the larger was the number of subjects who used them. There was, moreover, a corresponding increase in the number of advertisements put in these piles. But at no time did the number placed in piles No. 2 and No. 3 anywhere equal those placed in pile No. 1. This fact largely accounts for the scattered distribution in these two piles for when few advertisements are considered the percentages of right advertisements will vary much more than when many advertisements are considered. The medians representing the whole group, however, show with pile No. 2 the steady decrease in the validity of the recognitions and with pile No. 3 the approximation to 50 per cent., as already pointed out above.

The ratio between the validities of the three piles is given in Table III. where in each case the validity of the recognition in pile No. 1 is called 100. With the exception of the results from the set of 5 advertisements (where there were less than 10 subjects using piles No. 2 and No. 3) we have approximately three fourths the accuracy in pile No. 2 that we find in pile No. 1, and one half the accuracy in pile No. 3 that we find in pile No. 1. From these figures one might suppose that from an introspective standpoint the relation between pile No. 1 and pile No. 2 was maintained, *i. e.*, that although the actual results fell below the assigned standards, yet the relation between them was maintained. This point is upheld by the totals but a perusal of the distribution in Table IV. shows that it was not the case with the individual subjects. Although the writer does not feel that the data in this experiment are con-

clusive on this particular point, yet what data we do have point to the fact that the relationship of 100 per cent., 75 per cent. and 25 per cent. was not upheld, nor was there any constant relationship between the three piles. With each successive series, implying a difference in the difficulty of the task, the relationship between the three piles changed.

4. *Results Combining (1) the Number of Correct Recognitions and (2) the Validity of the Recognitions.*—At first thought it might be considered that the results presented in Table I. actually give the true relationship between length of series and the capacity to recognize. This would be so if all individuals took the same attitude of conservatism or optimism in selecting those advertisements they recognize. But this is not the case. Some will pick out only those advertisements they are absolutely sure of and will not use the second or third piles. The reason for their doing this is not entirely that recognition with them is either positive or lacking,—it may be partially due to this,—but it is due to a conservative temperament. My notes record a good many instances where such individuals have pointed out certain advertisements and exclaimed, "I think that was there," and yet put it in pile No. 4. If they followed instructions they should put it in pile No. 2 or pile No. 3 but they do not do so. They do not like to take chances. On the other hand, some individuals will take a chance on every advertisement, placing all those they are not absolutely sure of in piles No. 2 or No. 3 and not putting any in pile No. 4. As a general rule the conservative individual makes practically no mistakes in his first pile while the optimistic individual makes many. Now if we scored their results only in terms of the total number of correct recognitions, the latter's record would be much higher than the former's. On the face of it, such records are not true,—they do not represent the exact situation. It is for this reason that it is necessary to combine the two elements of amount of recognitions and their accuracy into one record. The method for doing this is as follows.

There are three factors which must be taken into account in obtaining a fair summary. There is first the number of advertisements that are correctly recognized,—the relationship

between the number recognized and the total number that should be recognized. There is second the accuracy of the recognitions,—the relationship between the number of correct and the number of incorrect recognitions. And there is third the general scheme of the experiment. In this experiment the subject had to select from an equal number of right and wrong advertisements. If this was changed so that he had to select from twice as many wrong as right advertisements the results would be different. In order to compare the results from two such experiments, the writer has multiplied the number of incorrect recognitions by such a factor as would equalize the chances between the right and wrong advertisements. For example, in the above case where twice as many wrong as right advertisements are presented to be chosen from, *i. e.*, when the chances are 1 to 2 in favor of selecting a right advertisement by chance, if the number of incorrect recognitions is multiplied by ½ we then have results of correct and incorrect recognitions which are comparable to those which would be obtained if the chances had been even at the start. Such a correction then takes account of the third factor which we are considering. No correction for this third factor,—the general scheme of the experiment,—need be made in this experiment as the chances of making a correct or incorrect recognition are already equal.

Turning now to the first factor we see at once that by reducing the total number recognized to per cent. of all that should have been seen we can compare directly the results from, say, a series of 5 advertisements with the results from any other series (just as is done in Table I.). Such a comparison is expressed by the formula,

$$\frac{\text{correct recognitions}}{\text{total number presented}}.$$

In presenting the second factor we must recognize that when there is an equal chance of selecting a right or wrong advertisement (when an equal number of each are presented as in this experiment) a record of 50 per cent. correct recognitions means nothing but pure chance. This 50 per cent. correct recognition

really means then nothing else than *zero memory* for although the subject has picked out x advertisements correctly from the n advertisements presented originally yet he has picked out an equal number incorrectly from those advertisements which had not been presented to him. As far as it is possible to consider the question we must consider that the n advertisements presented first have made no impression on him else they could be distinguished from the equal number that were not presented. We may then call *zero memory* in this case the condition where an equal number of right and wrong advertisements are picked out or where more wrong than right advertisements are selected. Actually this condition is never even approximated in the first pile and is only occasionally obtained in the second pile. *Perfect memory*, on the other hand, would be, of course, where the n advertisements presented were all recognized and none of the wrong advertisements were selected. The following formula,

$$\frac{\text{correct recognitions} - \text{incorrect recognitions}}{\text{correct recognitions} + \text{incorrect recognitions}},$$

will give 100 under those conditions corresponding to perfect memory as defined above, 0 under those conditions corresponding to zero memory as defined above, and equal steps between the two extremes as the factors vary successively.

By combining the two formulas and multiplying the results by 100 to have it read in terms of per cent. instead of a decimal we have

$$\frac{\text{correct recognitions}}{\text{total number presented}} \times \frac{\text{correct recognitions} - \text{incorrect recognitions}}{\text{correct recognitions} + \text{incorrect recognitions}} \times 100.$$

This formula combines the per cent. of correct recognitions among the possible recognitions with the accuracy of the recognitions. Some examples of the use of the formula will make this clear. Consider 10 advertisements shown and then the subject asked to pick out those he recognizes as having just seen from 20 advertisements consisting of the 10 he has seen

and 10 new ones. Suppose (1) he picks out all of the 10 correctly. We have then perfect memory, or the following:

$$\frac{10 \text{ (correct recog.)}}{10 \text{ (total no. presented)}}$$

$$\times \frac{10 \text{ (correct recog.)} - 0 \text{ (incorrect recog.)}}{10 \text{ (correct recog.)} + 0 \text{ (incorrect recog.)}} \times 100 = 100.$$

Suppose (2) he picks out 5 correct ones and 5 wrong ones. We have then,

$$\frac{5}{10} \times \frac{5 - 5}{5 + 5} \times 100 = 0.$$

And (3), suppose he picks out 5 correct ones and 1 incorrect one. We have then,

$$\frac{5}{10} \times \frac{5 - 1}{5 + 1} \times 100 = 33.$$

Having considered now the method for getting a true summary of amount of recognition and its accuracy let us apply the method to our present investigation. Table V. presents

TABLE V

RELATIONSHIP BETWEEN LENGTH OF SERIES AND RECOGNITION MEMORY

(The first column under each pile represents the per cent. of correct recognitions among the total possible number. The second column gives the validity of the recognitions, and the third column gives the product of the first two columns.)

No. of Ads.	Pile No. 1			Pile No. 2			Pile No. 3			Summary
5	82.3	98.5	81.1	4.5	60.9	2.7	2.3	0	0	83.1
10	81.5	97.8	79.7	4.5	51.8	2.3	2.5	.7	0	81.4
25	72.9	96.9	70.6	4.8	54.1	2.6	4.6	4.2	.2	72.6
50	61.6	90.3	55.6	6.0	32.8	2.0	5.0	3.3	.2	57.2
100	56.4	87.3	49.2	6.6	22.7	1.5	4.8	3.6	.2	50.4
150	40.4	83.4	33.7	7.0	25.6	1.8	4.6	3.3	.2	35.1

these results. In the first column under each pile is given the per cent. of correct recognitions among the whole number of possible recognitions. These figures are taken from Table I. and represent the results to be obtained from the first part of the formula. In the second column under each pile in Table V. is given the results which are obtained from the second part of the formula. The third column under each pile gives the product of the other two columns, which is again expressed in terms of

per cent. The summary is computed in the same way as are the ones in Tables I. and II., explained above. The data in this summary column are shown in diagram form in Plate III.

From this plate it is evident that the data all lie in a straight line except the results from the series of 25 and 50 advertisements. But as the probable error of the average of 50 advertisements is less than 2 it is extremely unlikely that its

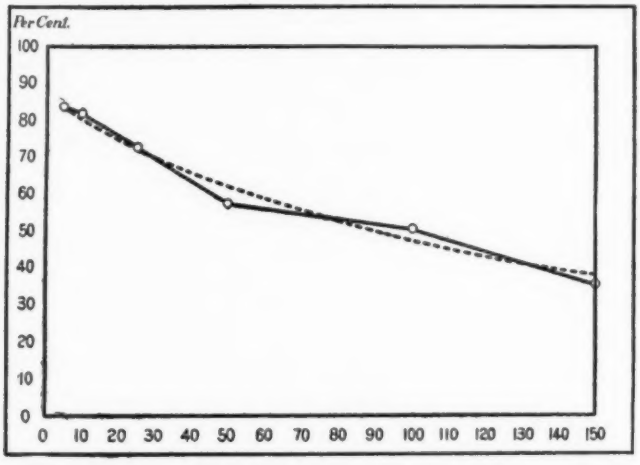

PLATE III. Showing the Relationship between length of Series and Recognition Memory (when amount and accuracy of recognitions are both considered).

true position lies in a straight line with the other figures, which would mean a displacement of ten or five times the probable error. The most probable "smooth curve" for the six points seems to be a curve similar to the one that is dotted in on the plate. This curve passes approximately through three of the six points and approaches fairly closely to the other three. If this is the true relationship, then, between length of series and recognition memory, we must conclude (1) that the per cent. of correct recognitions decreases more slowly than the length of the series increases and (2) that the rate of decrease is steadily decreasing as the length of the series increases.

Several other points of interest are suggested by Table V. The per cent. of correct recognitions in pile No. 1 decreases from 81 per cent. with a series of 5 advertisements to 34 per cent. with a series of 150 advertisements, in pile No. 2 the

decrease is from 2.7 per cent. to 1.8 per cent., while in pile No. 3 it is practically 0 per cent. throughout. Evidently then recognitions that are not accompanied with a feeling of "absolute certainty" are practically no better than random guesses. They are no better in pile No. 3 and only amount to 1.5 per cent. to 2.7 per cent. in pile No. 2, which represents "reasonable but not absolute certainty" or "75 per cent. certainty." This dearth of doubtful recognitions is due primarily to the fact that the subjects did not have such recognitions. Even in the series of 150 advertisements where we find the greatest number of them they only amount to 7.0 per cent. in pile No. 2 and 4.6 per cent. in pile No. 3 which together are only one fourth of the number in pile No. 1. But besides this dearth of doubtful recognitions there is also the fact that a very great number of those that were made turned out to be false recognitions. Practically none above those which would be expected from pure chance are found in pile No. 3. In pile No. 2 it is somewhat better. But even there we find only 33 per cent. more than what chance would warrant in the series of 50 advertisements and with the series of 100 and 150 advertisements the per cent. drops to 25 per cent.

Miscellaneous Notes

(*a*) No sex difference of any importance was noted.

(*b*) No correlation was found between ability in this experiment and "general intelligence" as indicated by (1) class-work and (2) the consensus of opinion of a subject's colleagues.

(*c*) Memory span when the objects are presented in succession is an entirely different thing from memory span when the objects are presented simultaneously.

Conclusion

1. When 5 advertisements are successively exposed 86 per cent. can be recognized immediately after, while only 47 per cent. can be recognized from 150 advertisements similarly exposed.

2. The per cent. of correct recognitions decreases as the length of the series increases. (This decrease is possibly faster at first and then steadily becomes less as the series are increased in length.)

3. When 5 advertisements are successively exposed and then recognitions are made from those advertisements and an equal number of wrong ones 1.7 per cent. of the latter will be incorrectly recognized as having been among those originally shown. In a series of 150 advertisements 8.3 per cent. of the wrong advertisements will be incorrectly recognized.

4. The per cent. of incorrect recognitions increases as the length of the series increases. This increase is more rapid at first and then becomes less and less as the series are increased in length.

5. Practically, very few incorrect recognitions are made as compared with the total of correct recognitions. It seems then that the ability to know we have not seen an object is much more strongly fixed than the ability to pick out what we have seen.

6. The accuracy of recognitions decreases rather slowly with "absolutely certain" recognitions and rather rapidly with "reasonably sure" recognitions as the length of the series increases, while it approximates zero with "very doubtful" recognitions regardless of the length of the series.

7. A true measure of recognition memory must take into account not only the per cent. of recognitions made out of the possible number but also the relationship between correct and incorrect or mistaken recognitions. When these two factors are considered we obtain a curve from which we deduce (1) that the per cent. of correct recognitions decreases more slowly than the length of the series increases and (2) that the rate of this decrease steadily decreases as the length of the series increases.

8. Recognitions not accompanied with a feeling of "absolute certainty" are practically no better than random guesses.

9. As the difficulty of the task increases the ratio of "absolutely certain" recognitions to "reasonably certain" and "doubtful" recognitions decreases. The first two groups actually also become less and less accurate but this decrease in accuracy is very marked in the "reasonably certain" group. The "doubtful" recognitions are practically worthless at all times.

THE EFFECT OF CHANGES IN THE GENERAL ILLUMINATION OF THE RETINA UPON ITS SENSITIVITY TO COLOR[1]

BY GERTRUDE RAND

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I. Introduction.
II. Historical.
III. Experimental.
(1) Quantitative estimate of the influence of change of illumination upon the induction of brightness by the surrounding field.
(2) The effects of these amounts of induction on the limits of color sensitivity.
(3) The effect of these amounts of induction on the limens of color at different degrees of excentricity.
(4) The influence of change of illumination upon the effect of the preëxposure on the limens and limits of color.
IV. Conclusion.

I. Introduction

It is the purpose of this paper to show the effect of changes in the intensity of the illumination of the field of vision upon the results of investigations which deal with the sensitivity of the retina to color.[2]

A method of standardizing the illumination of the field of vision was described in an earlier paper.[3]

II. Historical

The effect of the general illumination of the retina on color

[1] From the Bryn Mawr Psychological Laboratory.

[2] With regard to this effect two cases may be recognized: (1) When the colored light used to stimulate the retina is independent of the general illumination, *e. g.*, when it is obtained from the spectrum, from monochromatic sources, or from standard filters; and (2) when it is obtained by reflection from pigment surfaces. In the first case the effect is exerted in the following ways: (*a*) by changing the brightness relation of the preëxposure to the colored surface, (*b*) by changing the brightness relation of the surrounding field to the colored stimulus, (*c*) by altering the sensitivity of the retina to brightness after-image and contrast and thus changing the effect of the brightness of the preëxposure and of the surrounding field upon the sensitivity of the retina to the colored stimulus. To these effects is added in the second case a change in the amount of colored light coming to the eye.

[3] Ferree and Rand, 'An Optics-room and a Method of Standardizing its Illumination,' Psychol. Rev., 1912, XIX., pp. 364–373.

sensitivity has been recognized since the time of Purkinje and Aubert. It has been studied in some detail by a number of experimenters, among whom may be mentioned Kramer and Wolffberg. Both have shown that the sensation aroused by the colored stimulus is weakened by a reduction of the general illumination but neither has given a method of keeping the general illumination constant. Kramer's[1] purpose was to determine the sensitivity of the eye under different intensities of daylight and artificial illumination. His method was as follows. Stimuli, 4 mm. square, of blue, yellow, red, and green paper on a black background were used. The distance at which the stimulus had to be placed from the observer to be just recognized as colored was tested by sunlight and when the sky was obscured by clouds and for three intensities of each of the following sources of artificial illumination: candle-light, gas, petroleum, sodium, potassium, strontium, and calcium lights. His results show the following facts: (1) Red is seen at the greatest distance in all lights except calcium, in which case green is seen when placed farther away than red. The other colors are recognized in the order green, yellow, blue. (2) All the colors are recognized at a greater distance when seen by sunlight than when illumined by artificial light or the dull light from a clouded sky. (3) As the intensity of the artificial illumination is decreased, the colors must be placed nearer the eye to be recognized. In drawing his conclusions with regard to comparative sensitivity, Kramer ignored the white contrast which the black background induced across the stimuli. The induction across stimuli whose sizes were only 4 mm. square must have been considerable. It was, moreover, of different amounts in each case; because brightness contrast is greatest when there is maximal brightness opposition. The modification of the light colors, as a result of contrast induction, must, therefore, have been greater than that of the dark colors. Wolffberg's[2] interest was in the influence of gradual alterations of the general illumination on

[1] Kramer, J., 'Untersuchungen über die Abhängigkeit der Farbenempfindung von der Art und dem Grade der Beleuchtung,' Inaug.-Diss., Marburg, 1882.

[2] Wolffberg, 'Ueber die Prüfung des Lichtsinnes,' *A. f. O.*, 1887, XXXI., pp. 1–78.

the light and the color sensitivity of the central and of the peripheral retina. His room was illuminated by daylight entering through a window. Fifteen different degrees of illumination were produced by fastening from one to fifteen thicknesses of tissue-paper over the window. The illumination obtained when the window was uncovered was called 15/15; when covered with one thickness of tissue-paper, 14/15, etc. His method of determining the effect of variations of illumination upon the central retina was as follows: Pigment stimuli were placed at a standard distance of 5 meters from the observer, and the size of stimulus necessary to render it just visible in its true color was determined. In the peripheral retina, he investigated to what extent the limits of white and of colored stimuli were altered by reducing the illumination. In all his experiments, the stimuli were fastened on a black background. Wolffberg's results for the central retina are shown in the following table. The stimuli were circular in shape and of diameters given in columns 2, 3, 4, 5, and 6.

Illumination	Size of Red Stimulus	Size of Blue	Size of Green	Size of Yellow	Size of White
15/15	.5 mm.	3 mm.	3 mm.	1.5 mm.	.2 mm.
14/15	1.5	5	4	2	.5
13/15	2	6	6	4	1
12/15	2.5	12	12	4.5	2
11/15	3	20	20	5	2.5
.....	.....	.....	.....	.....	.....
5/15	10	50	50	10	6

These results show that in the central retina a decrease of illumination has greater effect upon the sensation of color than upon the sensation of white. Wolffberg next tested the effect of a gradual decrease of illumination upon the limits of sensitivity to white and to the colors. He found that the extent of the visual field was not narrowed for white when the illumination was decreased to 1/15. The color limits, however, narrowed gradually when the illumination was decreased from 15/15 to 3/15. The narrowing was in no case more than 15°. The relative extents of the fields remained unaltered, *i. e.*, the order of size was in every case blue, red, and green.

Although special investigations have been conducted by Kramer, Wolffberg, and others to show the effect of changes in the general illumination upon color sensitivity, in general little if any precautions have been taken by earlier experimenters to prevent such changes when investigating color sensitivity. Either the experimenter has not considered the influence of the general illumination, or he has been satisfied to take the rough precaution to work only on bright days at stated hours. Ole Bull,[1] for example, commented at length on the factor of general illumination, but suggested no method for its standardization. He writes: "The amount and nature of the general illumination are of more significance in perimetrical observations than one is accustomed to consider. It must always be noted whether the sky is clear or cloudy, whether it rains or snows. The extreme limits of the visual field for mixed light undergo such wide fluctuations that it is of little value to establish an average limit on the basis of a number of measurements. Changing illumination, conditioned by the time of day and of year during which the work is carried on, as well as the locality in which it is undertaken, produce variations in the same stimulus large enough to cause differences of from 10° to 20° [in the limit of sensitivity]. Especially in the nasal parts of the retina does the illumination influence the color limits, while their position remains more constant in the temporal retina." Fernald,[2] however, did make some attempt to obtain a standard illumination. She arranged white curtains at the windows of her optics-room, which could be lowered on bright days and drawn on dark days. This rather crude method was used also by Thompson and Gordon.[3] It is scarcely necessary to point out that the method lacks the first essential of standardization, namely, a means of measuring.

It is surprising that Wolffberg, as the logical corollary of his work, did not draw attention to the importance of standard-

[1] Ole Bull, 'Perimetrie,' Bonn, 1895, p. 8.

[2] Fernald, G. M., 'The Effect of the Brightness of Background on the Extent of the Color Fields and on the Color Tone in Peripheral Retina,' PSYCHOL. REV., 1905, XII., p. 392.

[3] Thompson and Gordon, 'A Study of After-images on the Peripheral Retina,' PSYCHOL. REV., 1907, XIV., p. 122.

izing the illumination of the visual field in all work on the color sensitivity of the retina, and show how it could be accomplished by a modification of his method of working. He already had at hand one of the essentials for standardizing, namely, a method of changing the illumination of his room. The other essential, a method of measurement by means of which an illumination could be identified with a previous illumination chosen as standard, might have been derived from his results. For example, it would seem to have been a simple matter for him to have chosen as standard the particular illumination at which the red stimulus of 2.5 mm. diameter, the blue and green of 12 mm. each, the yellow of 4.5 mm., and the white of 2 mm. were just recognizable at a distance of 5 m. Stimuli of these sizes, it will be seen from the tables, were just recognizable at this distance at the illumination called 12/15, when 15/15 represents the illumination "bei günstige Tagesbeleuchtung." Using this condition as an index of the standard illumination, he could at any time have adjusted the illumination of the room by adding to or subtracting from the layers of tissue-paper covering the window, until the stimuli of these sizes were again just recognizable at the given distance. The accuracy and sensitivity of this method could have been tested by comparing the results of a series of determinations. An accurate and highly sensitive method sustaining some similarity in principle to the method suggested here is described in another paper in this volume of the REVIEW.[1]

III. EXPERIMENTAL

The effect of change of illumination was forced upon our attention early in the investigation of the factors that influence the color sensitivity of the retina. For example, in preliminary work done by the writer on a well-lighted porch on Long Island, changes in color-tone were observed, when certain colors were compared in the central and in the peripheral retina, that are not found at all under the more intensive illumination of our optics-room when neither of the curtains is

[1] See footnote 2, p. 1.

drawn; and the peripheral limits of color were narrower by 5° to 12°. Furthermore, on a dark day, it was found that the limits of stimuli exposed through an opening in a white screen were reduced by about 4° as compared with the limits taken on a bright day. The change was less considerable with black and gray screens. The change in color-tone was most conspicuous in case of green.[1] On dark days, the green stimulus appeared as a pale unsaturated blue before becoming colorless in passing from the center to the periphery of the retina. This zone of blue was from 7° to 23° wide, in different meridians of the retina, with both white and black screens, but was wider with the black than with the white screen. On a sunny day, on the other hand, with the white screen green passed into bluish-green, then directly into gray, except in case of the upper regions where it appeared blue throughout a zone of about 4° in width. With the black screen, the blue zone was found only in the upper and temporal regions of the retina. The transition of green to yellow in the periphery that is generally reported in the literature was found in these experiments only when the gray screen was used. Yellow showed a color change that varied in amount with the degree of the general illumination. On a bright day with the white screen, it appeared reddish-orange. On a cloudy day, it was seen in the extreme periphery as a dark saturated red.

Working in our optics-room we found also that results taken on one day could not at all be duplicated on the following day. When the work was carried on under the most favorable conditions without special means of controlling illumination, namely, on bright days only, differences of 5° or more were found when the white screen was used. This necessitated a long series of observations if legitimate averages were to be obtained. Such a procedure is at best a poor makeshift and is besides of great disadvantage in many problems that come up in the work on color sensitivity. Particular instances of this may be found in investigations in which it is required to work in the region lying just within the limits of sensitivity, and in work on the after-images of stimuli in which no color is sensed.

[1] The green of the Hering series was used.

In the latter case the experiment requires that the stimulus be exposed just outside the limits of sensitivity determined with a given brightness condition, and that the observer should not be aware of the nature of the stimulus. In order to fulfill these requirements the experimenter must know the limits obtaining with a given brightness condition. It would be impossible to know this when the brightness conditions were subjected to the influence of changing illumination unless re-determinations were made at the beginning of each sitting and even frequently during its course. This would consume a great deal of time and would, besides, only roughly fulfill the requirements of the problem. A further and still more important example of the disadvantage may be found in the task we had set ourselves, namely, to investigate from point to point the sensitivity of the retina to each of the principal colors for three backgrounds in at least sixteen different meridians. In this work it is obvious that unless a standard illumination were provided, all comparative work would have to be done at one sitting. This is impossible. When time is taken between observations to guard against fatigue, at least three hours is required merely to outline the limits of sensitivity for a given color with one background for only one half of the retina. Even for this length of time there is no guarantee that the illumination has not altered. Thus at the outset of any extended investigation of color sensitivity, it is evident that, without a standard illumination, results will be of little comparative value.

In order better to know our factor and the ways in which it operates, a systematic investigation of the influence of changes of general illumination was carried on in our optics-room which is especially constructed to secure fine changes in illumination.[1] The experimentation was conducted by means of a rotary campimeter, described in full by Ferree, in the July number of the *American Journal of Psychology*.[2] Three observers acted as subjects. Since the results of all three are

[1] A description of this optics-room was given in the PSYCHOLOGICAL REVIEW, September number, 1912, pp. 367–368.

[2] Ferree, C. E., 'Description of a Rotary Campimeter,' *Amer. Journ. of Psychol.*, 1912, XXIII., pp. 449–453.

similar in their general bearing on the problem, space will be taken for the results of two of them only, *A* and *C*.

Rough preliminary experiments showed that the primary effect of decreasing the illumination was an increase in the amount of contrast induced across the stimulus by the campimeter screen. With the white screen, the increased induction was the most pronounced and was sufficient to cause large changes in the limits and in the color-tone of the stimulus. In order to investigate this effect in detail, gradual changes of illumination covering a wide range were made by means of the curtains with which our optics-room is furnished. Attention was given to the following points. (1) A quantitative estimate was made of the influence of change of illumination upon the brightness induction of the campimeter screen. (2) The effect of this induction upon the limits of color sensitivity was determined. (3) The limens of the colors were measured at different degrees of excentricity at different illuminations. And (4) the influence of change of illumination upon the effect of the preëxposure on the limens and limits of color was investigated. The degrees of illumination chosen for comparison were the standard illumination, the method of obtaining which was described in an earlier paper,[1] and a decreased illumination which was similar to that obtaining on a cloudy afternoon. Measured in foot-candles by means of the Sharpe-Millar portable photometer, the standard illumination equalled 390 foot-candles, the decreased 1.65 foot-candles.

1. Quantitative Estimate of the Influence of Change of Illumination upon the Induction of Brightness by the Surrounding Field

The purpose of this investigation was to find out (1) how much the induction from white and black screens[2] is affected by a change in the general illumination; and (2) how much induction is gotten at decreased illumination from the gray screen which matches the color at standard illumination. The

[1] Ferree and Rand, *op. cit.*

[2] White and black screens are chosen because they represent the extreme cases of the effect of change of illumination.

induction in this latter case is caused by the change in the brightness relation between color and screens with decrease of illumination.[1] The campimeter screens served as inducing surface, grays of the brightness of the four principal colors of the Hering series both at standard and decreased illumination were used in turn as stimuli, and the amount of induction was estimated upon a measuring-disc, made up of adjustable sectors of the gray of the stimulus and white or black, according to the screen used. The measuring-disc was mounted on a motor which could be moved along the graded arm of the campimeter to any position from 20° to 92°. The gray stimulus was exposed through the opening of the screen in the usual manner. Two preliminary precautions were observed. (*a*) Since the brightness of the gray stimulus plus the induction of the screen was to be estimated by means of the measuring-disc, and since the brightness-value of the stimulus and of the disc changes with the amount of light that falls upon them, it was necessary to make sure before each measurement that the same amount of light fell upon each. This precaution was all the more necessary because the stimulus had to be placed behind the screen and the measuring-disc in front. In a given position of the apparatus, one or the other was apt to be shaded. The determination was made as follows: Measuring-disc, campimeter screen, and gray stimulus were all given the same brightness-value according to determinations made under conditions about which no doubt of the equality of the illumination of each could be entertained. Each was then placed in position for the experiment, and the position of the campimeter as a whole and of its various parts was adjusted until stimulus, screen, and measuring-disc were exactly matched in brightness-value. When an exact match was obtained we were guaranteed

[1] This latter determination is made to show that it is impossible to standardize the brightness of the surrounding field against the sudden and progressive changes of daylight that occur during the course of a single series of observations. These changes alter the brightness relation between the colored stimulus and the gray used as screen; therefore a match made at the beginning of a series will not hold throughout its course. For the same reason and to an equal degree the brightness relation between preëxposure and colored stimulus changes with change of illumination. It is, therefore, equally impossible to standardize the brightness of the preëxposure without some means of securing a standard illumination.

that all three were again equally illuminated. (*b*) The question arose whether brightness induction comes to its maximal value at once in the peripheral retina. A determination of the intensity curve of the contrast sensation was accordingly made at various points in the peripheral retina. It showed that contrast increases strongly for the first few seconds of stimulation. For this reason it was found to be necessary to make the judgment concerning the amount of induction of the screen, just as long after the induction had commenced as was done in the experiments to determine color sensitivity. In the color experiments an interval has to be allowed before the stimulus is exposed during which the observer obtains a steady fixation. During this interval of preëxposure, the eye is being stimulated by the campimeter screen and by the card which covers the stimulus. To prevent the preëxposure card from giving a brightness after-image which would fuse with and modify the stimulus, it should be chosen of a gray of the brightness of the color. In the same way, an interval has to be given in which to secure steady fixation when the amount of brightness induction is being measured. In order, then, to have the judgments made in each case the same length of time after induction had begun, it was necessary only to make the intervals of preëxposure of equal duration and to require that the judgments of each kind be made directly at the end of the preëxposure. In the case of the color experiments, the signal for the making of the judgment is the withdrawal of the preëxposure card and the exposure of the stimulus. For the judgments of induction, however, in which case the stimulus was the gray of the brightness of the color, it is obvious that no preëxposure card was needed, for preëxposure and stimulus were required by the conditions of the experiment to be the same. In this case, a word-signal had to be given to indicate the termination of the preëxposure interval and the instant at which the judgment was to be made.

Results when White and Black Screens were Used.—Observing these precautions as to the equality of the illumination of stimulus, screen, and measuring-disc, and as to the length of time the induction had had in which to increase before the

judgment was made, measurements were taken of the induction by white and black screens across grays of the brightness of the four principal colors at the illumination used. These measurements were made at various points of excentricity on the retina and for both standard and decreased illumination. The determination of the equality point between the stimulus and the measuring-disc was made as follows: The size of the white or black sector of the latter was changed until a preliminary judgment of equality was made. Then the j. n. d. on either side of this point was determined both by ascending and by descending series and an average of the results was taken as the final value of the induction. Measurements were taken at 25° and 40° on the temporal meridian, and at 55° and 70° on the nasal. The conditions at the nasal 55° point were very similar to those at 25° on the temporal side. The measurements at 70° nasal were midway in value between those at 25° and 40° on the temporal. The 40° point is very near the limits of color sensitivity in this meridian, and the induction here is very great. For one observer, the darker stimuli appeared black at this point, when the white background was used. In such cases, the difference between the induction at standard and at decreased illumination is more clearly shown by the observations made at 25° temporal meridian and at 55° and 70° nasal meridian than at 40° temporal. We have, however, chosen for two reasons to present in the following table only the results obtained in the temporal meridian. (1) The results obtained in this meridian demonstrate sufficiently well all the facts that need be taken into consideration. Space will not, therefore, be given to the results for both meridians. (2) The second point of our problem requires us to correlate the increased amount of induction caused by a given decrease of illumination with the change in the color limits it produces. The limits of color sensitivity can be more easily investigated in the temporal meridian because the sensitivity to some colors extends in the nasal region beyond the 92° point, which is the limit of measurement for the apparatus we used. This is true in particular in case of observer *C* as may be seen in Table XI. Both purposes of the investigation are, then,

better satisfied by results obtained in the temporal meridian.

The results show in general the following facts.

1. The amount of induction from the white screen is greater than that from the black screen.

2. The amount of induction increases with the distance from the fovea.

3. The amount of induction increases with decrease of illumination.[1]

4. The amount of increase under decreased illumination is greater in case of the white screen than in case of the black screen.

5. The white and black screens induce more contrast across the stimuli that are farthest removed from them in brightness, and least across those which are most like them. That is, the white screen induces more black across the gray of the brightness of blue than across a gray of the brightness of yellow; and the black screen induces more white across the gray of the brightness of yellow than across a gray of the brightness of blue.

Results are given in detail in Tables I. and II. Table I. gives the results for observer *A* taken on the temporal meridian, and Table II., the results for observer *C* for the same meridian. There is some difference in the amount of induction reported by the different observers, but since the preceding general statement of results is clearly borne out in every case, it is not deemed necessary to give space to results from all the observers used. In these tables, column 1 gives the degree of excentricity at which the observation was made; columns 2, 3, and 4 show respectively the stimulus used, and the amounts of induction from the white and the black screens at standard illumination. Columns 5, 6, and 7 give the same data for decreased illumination.

Results when the Gray Screen Matching the Colored Stimulus in Brightness at Standard Illumination is Used.—It was neces-

[1] This statement is meant to apply only to the range of illumination worked with. The induction was not measured when the illumination was very low, nor when it was very intensive.

TABLE I

A. SHOWING THE AMOUNT OF CONTRAST INDUCED BY THE WHITE AND THE BLACK SCREENS AT STANDARD AND DECREASED ILLUMINATION UPON THE GRAYS OF THE BRIGHTNESSES OF THE COLORED STIMULI AT STANDARD AND DECREASED ILLUMINATION[1]

Fixation	Standard Illumination			Decreased Illumination		
	Stimulus (Gray of Brightness of Each of the Four Colors at Standard Illumination)	Amt. Induction of White Screen	Amt. Induction of Black Screen	Stimulus (Gray of Brightness of Each of the Four Colors at Decreased Illumination)	Amt. Induction of White Screen	Amt. Induction of Black Screen
25°	gray No. 2	Black 135°	White 110°	gray No. 2	Black 220°	White 170°
	gray No. 8	Black 155°	White 60°	gray No. 6	Black 270°	White 80°
	gray No. 24	Black 230°	White 28°	gray No. 41	Black 323°	White 40°
	gray No. 32	Black 290°	White 12°	gray No. 20	Black 330°	White 30°
40°	gray No. 2	Black 200°	White 300°	gray No. 3	Black 320°	White 360°
	gray No. 8	Black 300°	White 132°	gray No. 5	Black 360°	White 180°
	gray No. 24	Black 0°	White 60°	gray No. 50	Black 360°[2]	White 0°[2]
	gray No. 29	Black 360°	White 28°	gray No. 13	Black 360°	White 100°

[1] It is obvious that the method of expressing the amount of brightness induction used in this and the following tables gives an underestimation. Suppose, as is shown in Table I., that No. 24 Hering gray has been darkened by induction until it matches in brightness a disc made up of 230° of black and 130° of the No. 24 gray. The amount of induction is greater than is represented by the 230° of black because the induction has not lessened the amount of light coming to the eye from the grey paper while the addition of 230° of black to the measuring-disc has cut off approximately 2/3 of the light coming from the gray paper. That is, in the one case enough black has been added by induction to reduce 360° of No. 24 gray to the given point in the brightness scale, while in the other enough black was added by direct mixing to lower only 130° of No. 24 gray to this point in the scale. Moreover, the underestimation will be increased by this method of measuring in proportion as the amount of induction is increased because the greater the induction is the more black and the less gray will have to be used in the measuring-disc. All that can be said accurately is that a certain gray darkened or lightened by induction matches in brightness a gray made up of a certain amount of the given gray plus a certain amount of black or white. The exact amount of the induction can not be separated out. Further, just because the brightness added by contrast does not alter the amount of light coming to the eye while the brightness added in any method of measurement does change this amount of light, the writer knows of no way by which an exact expression can be attained. The

TABLE II

OBSERVER *C*

Fixation	Standard Illumination			Decreased Illumination		
	Stimulus (Gray of Brightness of Each of the Four Colors at Standard Illumination)	Amt. Induction of White Screen	Amt. Induction of Black Screen	Stimulus (Gray of Brightness of Each of the Four Colors at Decreased Illumination)	Amt. Induction of White Screen	Amt. Induction of Black Screen
25°	gray No. 2	Black 70°	White 55°	gray No. 2	Black 130°	White 70°
	gray No. 8	Black 84°	White 48°	gray No. 6	Black 155°	White 59°
	gray No. 24	Black 93°	White 30°	gray No. 40	Black 187°	White 45°
	gray No. 32	Black 160°	White 15°	gray No. 17	Black 244°	White 22°
40°	gray No. 2	Black 110°	White 200°	gray No. 3	Black 216°	White 340°
	gray No. 7	Black 142°	White 160°	gray No. 4	Black 230°	White 320°
	gray No. 24	Black 180°	White 95°	gray No. 50	Black 360°[4]	White 0°[5]
	gray No. 27	Black 214°	White 35°	gray No. 7	Black 300°	White 108°

method she has used, however, does serve as a means of comparing the amounts of induction occurring under different conditions sufficiently accurately for her purpose at this point.

[2] The gray No. 50 was in reality rendered blacker by the inductive action of gray No. 24 than the Hering black we used on the measuring-disc. A match thus could not be attained with black 360° as the table indicates.

[3] There was no brightness induction in this case because the stimulus, gray No. 50, matches in brightness the black paper which formed the campimeter screen.

[4] See footnote 2 above.

[5] See footnote 3 above.

sary to perform the experiments bearing on this point at decreased illumination only. For them the campimeter screens which matched in brightness the four principal colors of the Hering series at standard illumination served as inducing surfaces. For the contrast surfaces, grays of the brightness of these colors at decreased illumination were chosen. The methods of measuring, precautions in working, parts of the retina investigated, etc., were the same as in the preceding determinations. The following general statement of results may be made. (1) At the 25° point the brightness of yellow was found not to have changed at all with the decrease of illumination produced by changing the illumination from the value selected as standard to the value selected for the comparison; the brightness of green lightened by an amount equal to the difference between No. 8 and No. 6 of the Hering series of grays; red darkened by an amount equal to the difference between No. 24 and No. 40; and blue lightened by an amount equal to the difference between No. 32 and No. 20. The amount of induction by the gray screen of the original brightness of the color upon the gray stimulus of the brightness of the color as altered by the decreased illumination, expressed in terms of Hering white and black, was for yellow 0°, for green 60° of white, for red 27° of black, and for blue 20° of white. (2) At the 40° point, the yellow darkened by an amount equal to the difference between No. 2 and No. 3 of the Hering grays; green lightened by an amount equal to the difference between No. 8 and No. 5; red darkened by an amount equal to the difference between No. 28 and No. 50; and blue lightened by an amount equal to the difference between No. 28 and No. 13. The amount of induction produced by these changes was for yellow 280° of black, for green 130° of white, for red 360° of black, and for blue 60° of white. These results are shown in detail in Table III.

2. The Effect of These Amounts of Induction Upon the Limits of Color Sensitivity

In order to obtain an estimate of the range of effect upon the limits of color sensitivity of the induction of the screens

TABLE III

A. SHOWING THE AMOUNT OF CONTRAST INDUCED AT DECREASED ILLUMINATION ON GRAYS OF THE BRIGHTNESS OF THE COLORS AT DECREASED ILLUMINATION BY THE GRAY SCREENS MATCHING THE COLORS IN BRIGHTNESS AT STANDARD ILLUMINATION

Fixation	Stimulus	Screen	Amount of Induction
25°	gray No. 2	gray No. 2	0°
	gray No. 6	gray No. 8	white 60°
	gray No. 41	gray No. 24	black 27°
	gray No. 20	gray No. 32	white 20°
40°	gray No. 3	gray No. 2	black 280°
	grgy No. 5	gray No. 8	white 130°
	gray No. 50	gray No. 24	black 360°[1]
	gray No. 13	gray No. 28	white 60°

at standard and at decreased illumination, the breadth of the color zones was determined at both illuminations (1) when white and black served in turn as campimeter screens; and (2) when a gray matching the color in brightness at standard illumination was used. The preëxposure was in each case to a gray of the same brightness as the stimulus at the illumination used. The point at which the color lost all trace of its original quality was recorded as the limit of sensitivity.

Results when White and Black Screens Were Used.—When the stimulus color is gotten by reflection from a pigment surface, two factors operate to give a change of result when the illumination is decreased. (1) There is a decrease in the amount of colored light coming to the eye. (2) There is an increase in the inductive action of the screen due to the change in the brightness relation of stimulus to screen and to the increased sensitivity of the eye to brightness contrast at decreased illumination.

In order to find out how much of our results with the white and black screens should be attributed to the decrease in the amount of colored light coming to the eye produced by the decreased illumination, and how much to the increased inductive action of the screens, the limits of sensitivity were also determined at both illuminations with the screens of the gray into

[1] The gray No. 50 was in reality rendered blacker by the inductive action of gray No. 24 than the Hering black we used on the measuring-disc. A match thus could not be attained with black 360° as the table indicates.

which the color disappears in the peripheral retina. From the values obtained with the three screens at both illuminations, the amount of change due to decrease in the amount of colored light coming to the eye and the amount due to induction by the white and black screens were calculated as follows. (*a*) From the number of degrees expressing the limits for a given color at standard illumination with a screen of the brightness of the color at that illumination was subtracted the number expressing its limit at decreased illumination with a screen of the brightness of the color at the decreased illumination. That this gave the number of degrees the zone of sensitivity was narrowed by the decrease in the energy of the stimulus may be said with the following qualification. If there is any influence upon color sensitivity of the local brightness-adaptation of the retina produced by the change in the general illumination, it is, of course, included in this effect. But, since this influence would have to be brought about by previous exposure to the illumination in question, it can be reduced to a minimum by guarding against an exposure to it for any considerable length of time. The effect of whatever adaptation there may be, however, can not be isolated or separated out from the above result, and the value expressing the amount the limit is narrowed by the actual decrease of the energy of colored light coming to the eye cannot, strictly speaking, be obtained. But it is probable that the adaptation effect is not sufficiently strong to influence the limits, since the sensitivity of the extreme peripheral retina falls off very abruptly from point to point. The difference, then, between the color limit obtained at standard illumination and the limit at decreased illumination, when in both cases there is no brightness induction from the screen, may be said to approximate the effect upon the limits produced by the decrease in the amount of colored light coming to the eye. (*b*) Figures can be obtained, however, from our results, which express the amount by which the zones are narrowed by the change in the inductive action of the white and black screens produced by decreasing the illumination, that are not open to theoretical questioning; for the influence of local brightness-adaptation, if there be any, is a constant for all screens at the same illu-

mination. If then, the number of degrees which expresses the limits of sensitivity for either the white or the black screen at decreased illumination is subtracted from the number expressing the limit with a screen of the gray of the brightness of the color at this illumination, the result will represent the extent to which the limit was narrowed by the action of induction alone. The results show in general the following facts:

1. At standard illumination, induction from the white screen narrows the limits of yellow and red; induction from the black screen narrows the limits of blue and green. The difference is in no case more than 4°.

2. At decreased illumination, the induction from the white screen narrows the limits of all the colors much more considerably than does the induction from the black screen.[1]

3. The values expressing the narrowing of the limits caused by decrease of illumination without induction are greatest in case of those colors which undergo maximum change of brightness in passing into the periphery, namely, for blue and red.

We have shown by the results of the preceding section, that the increased induction produced by decrease of the general illumination is greater for the white screen than for the black, and, by the results of this section, that this increase is effective to the extent of narrowing the limits of sensitivity to all colors from 5° to 12° with this screen. With the black screen, the limits were narrowed from 3° to 6°. At standard illumination, the limits were narrowed only from 1° to 4° with either the white or the black screens.

Results in detail are given in Tables IV. and V., taken from the temporal meridians of the observers whose observations are recorded in Tables I. and II. In column 1, Tables IV. and V., is given the stimulus. Column 2 shows the limit of sensitivity to the stimulus at standard illumination with a screen of a

[1] For observer *A* the results for green present an exception. At the decreased illumination used the green stimulus appeared bluish in the central retina. The induction of the black screen caused it to appear as a pale blue at a comparatively slight degree of excentricity. According to our definition of color limit, this point is the limit of green. It is, however, obvious that the exception is due rather to the qualitative than to the quantitative effect of brightness upon color.

gray of the brightness of the color at standard illumination; column 3 shows the limit with a white screen; and column 4 with a black screen. Column 5 shows the limit at decreased illumination with a screen of the brightness of the color at decreased illumination; column 6 shows the limit with a white screen; and column 7 with a black screen.

TABLE IV

A. SHOWING THE COLOR LIMITS AT STANDARD AND DECREASED ILLUMINATION (*a*) WITH GRAY SCREENS OF THE BRIGHTNESSES OF THE COLORS AT THE ILLUMINATION USED; AND (*b*) WITH WHITE AND BLACK SCREENS

Stimulus	Standard Illumination			Decreased Illumination		
	Limit with Gray Screen of Brightness of Color at Standard Illumination	Limit with White Screen	Limit with Black Screen	Limit with Gray Screen of Brightness of Color at Decreased Illumination	Limit with White Screen	Limit with Black Screen
Yellow.....	44°	42°	45°	43°	35°	43°
Green	37°	37°	34°	36°	31°	27°
Red.....	43°	42°	44°	40°	31°	40°
Blue.....	50°	50°	49°	48°	36°	43°

TABLE V

OBSERVER *C*

Stimulus	Standard Illumination			Decreased Illumination		
	Limit with Gray Screen of Brightness of Color at Standard Illumination	Limit with White Screen	Limit with Black Screen	Limit with Gray Screen of Brightness of Color at Decreased Illumination	Limit with White Screen	Limit with Black Screen
Yellow.....	49°	46°	50°	46°	36°	44°
Green	44°	42°	40°	41°	28°	33°
Red.....	45°	41°	45°	41°	34°	41°
Blue.....	56°	55°	53°	50°	38°	44°

Tables VI. and VII. have been compiled from Tables IV. and V. to show the following facts.

(1) How much the decrease of illumination narrowed the limits of color sensitivity by causing a decrease in the energy of the light waves coming to the eye. This was determined by subtracting the value of the limit at decreased illumination with the screen of a gray of the brightness of the color at decreased illumination from its value at full illumination with the gray screen of the brightness of the color at full illumination.

(2) How much the limits were narrowed by the action of the white and black screens at decreased illumination. This was ascertained by subtracting the values of the limit with the white and the black screen at decreased illumination from the value of the limit at decreased illumination with the gray screen of the brightness of the color at this illumination. (3) How much more the limits were narrowed by the white and the black screens at decreased than at full illumination. This was computed for the white screen, for example, as follows. The quantity, limit at decreased illumination for gray screen of brightness of color at decreased illumination, minus limit for white screen at decreased illumination, is subtracted from the

TABLE VI

A. SHOWING (1) HOW MUCH THE LIMITS WERE NARROWED BY DECREASE IN THE AMOUNT OF COLORED LIGHT COMING TO THE EYE; (2) HOW MUCH THEY WERE NARROWED BY INCREASED INDUCTION OF WHITE AND BLACK SCREENS AT DECREASED ILLUMINATION; AND (3) HOW MUCH MORE THEY WERE NARROWED BY INDUCTION OF WHITE AND BLACK SCREENS AT DECREASED THAN AT FULL ILLUMINATION

Stimulus	How Much Limits were Narrowed by Decrease in Amount of Colored Light Coming to the Eye	How Much Limits were Narrowed by Induction of White Screen	How Much Limits were Narrowed by Induction of Black Screen	How Much More Limits were Narrowed by White Screen at Decreased than at Full Illumination	How Much More Limits were Narrowed by Black Screen at Decreased than at Full Illumination
Yellow.....	1°	8°	0°	6°	3°
Green	1°	5°	9°	5°	6°
Red.....	3°	9°	0°	8°	3°
Blue.....	2°	12°	5°	12°	4°

TABLE VII

OBSERVER *C*

Stimulus	How Much Limits were Narrowed by Decrease in Amount of Colored Light Coming to the Eye	How Much Limits were Narrowed by Induction of White Screen	How Much Limits were Narrowed by Induction of Black Screen	How Much More Limits were Narrowed by White Screen at Decreased than at Full Illumination	How Much More Limits were Narrowed by Black Screen at Decreased than at Full Illumination
Yellow.....	3°	10°	2°	7°	3°
Green	3°	13°	8°	11°	4°
Red.....	4°	7°	0°	3°	0°
Blue.....	6°	12°	7°	11°	3°

quantity, limit at full illumination for gray screen of brightness of color at full illumination minus limit for white screen at full illumination. A similar computation was made for the black screen.

Results when a Gray Screen Matching the Color in Brightness at Standard Illumination is Used.—In these experiments a determination was made of the amount the limits of sensitivity are changed by the brightness induction caused by the alteration of the brightness relation between stimulus and screen with decrease of illumination, when a screen is used which matches the color in brightness at standard illumination. This determination was made as follows. An estimate was made of the amount the limits were narrowed by decrease of illumination when a screen of the brightness of the color at standard illumination is used for both standard and decreased illuminations. From this result was subtracted the amount the limits were narrowed by decrease of illumination when the screen is made in turn of the brightness of the color at standard and decreased illumination. The difference obtained represents the value sought. It is given in Table VIII.

TABLE VIII

A. SHOWING HOW MUCH THE COLOR LIMITS WERE NARROWED AT DECREASED ILLUMINATION BY THE INDUCTION OF THE SCREEN WHICH MATCHED THE COLOR IN BRIGHTNESS AT STANDARD ILLUMINATION

Stimulus	Screen of Brightness of Color at Decreased Illumination	Limit	Screen of Brightness of Color at Standard Illumination	Limit	Amount Limit was Narrowed by Change in Brightness Relation Between Stimulus and Screen Caused by Decreased Illumination
Yellow...	gray No. 3	43°	gray No. 2	41°	2°
Green ...	gray No. 5	36°	gray No. 8	29°	7°
Red	gray No. 50	40°	gray No. 24	33°	7°
Blue.....	gray No. 13	48°	gray No. 28	46°	2°

3. THE EFFECT OF THESE AMOUNTS OF INDUCTION UPON THE LIMEN OF COLOR AT DIFFERENT DEGREES OF EXCENTRICITY

We have shown the effect of decreasing the general illumination upon the color sensitivity of the peripheral retina with

gray, white, and black screens, by the effect on the limits of sensitivity. This is only an indirect means of estimating its influence, for the results obtained cannot be translated into terms of direct measurement, owing to the irregular decrease in sensitivity of the peripheral retina from the fovea outwards. In this section, we shall measure the influence of changes of illumination directly by the changes produced in the limen of sensation at various angles of excentricity. As in the previous section, measurement will be made of the effect upon sensitivity (1) of the decrease in the amount of colored light coming to the eye, produced by the decrease of illumination, (2) of the difference in the inducing power of the white and black screens, and (3) of the change in the brightness relation of stimulus to background.

To determine the first of these three points, a campimeter screen had to be selected that gave no brightness contrast with the stimulus. To provide for differences in the brightness of the colors at the different points observed for the two illuminations at which we worked, a preliminary determination of the brightness of the sensation at these points was made at both illuminations by the flicker method. The brightness of the screen was chosen in each case of the brightness of the color according to these determinations. To eliminate the effect of preëxposure, the stimulus previous to exposure was in every case covered by a gray of the brightness of the color for the illumination used at the point of the retina at which we were working. Thus no brightness after-image was carried over to exert an inhibitive action upon the color sensation. The stimulus was a disc compounded of sectors of the color and of the gray of the brightness of the color for the illumination used at the point of the retina under investigation. The proportions of the sectors were altered until the observer gave the judgment of just noticeable color. The average of judgments made in ascending and descending series was chosen as the final value of the limen. The difference between the limens at standard and decreased illumination was taken as the measure of the loss in intensity which the stimulus had sustained by the decrease of illumination.

The effect upon the color limen of the increased induction from the white and black screens was shown by the same method, with the exception that the white and black screens were substituted for the gray of the brightness of the color. The stimulus was a disc composed of sectors of color and gray of the brightness of the color at the angle of excentricity at which the determination was made.

The effect of the change in the brightness relation between the stimulus color and the screen produced by decrease of illumination was shown as follows. An estimate was made of the amount the limens are raised by the decrease of illumination when a screen was used for both standard and decreased illumination that had a brightness value equal to the color at standard illumination. From these results was subtracted the amount the limens were raised by decreasing the illumination when the screens were made in turn of the brightness of the color at standard and at decreased illumination. The difference obtained represents the value sought. These results are of particular importance because they show that the influence of the brightness of the surrounding field can not be eliminated even when a screen of the brightness of the color is used unless some means be had of maintaining the general illumination of the room constant.

Table IX. shows how much the limens of sensitivity were raised at the fovea and at points 15°, 25° and 30° from the fovea in the horizontal meridian on the temporal side by the decrease in the amount of colored light coming to the eye produced by the decrease in the general illumination. The results of this table may be generalized as follows:

1. The limen of color is higher in the periphery than in the center of the retina at both illuminations.

2. The limen of color is higher at decreased illumination that at standard illumination.

3. The direct effect upon the intensity of the sensation produced by decreasing the illumination is shown by the limen determinations to be inconsiderable. In the central retina, the difference is but 2° or 3°. In the peripheral retina at the points considered there is a difference of from 10° to 20°.

TABLE IX

A. SHOWING HOW MUCH THE LIMENS OF SENSITIVITY WERE RAISED AT THE FOVEA, AND AT POINTS 15°, 25°, 30° FROM THE FOVEA IN THE HORIZONTAL MERIDIAN ON THE TEMPORAL SIDE BY THE DECREASE IN THE AMOUNT OF COLORED LIGHT COMING TO THE EYE PRODUCED BY THE DECREASE IN THE GENERAL ILLUMINATION

Stimulus	Point on Horizontal Temporal Meridian at Which Limen was Taken	Limen at Standard Illumination with Screen of Brightness of Color at Standard Illumination	Limen at Decreased Illumination with Screen of Brightness of Color at Decreased Illumination	How Much Limen was Raised at Decreased Illumination
Yellow.....	0°	18°	20°	2°
	15°	22°	32°	10°
	25°	35°	40°	5°
	30°	50°	65°	15°
Green	0°	20°	20°	0°
	15°	27°	28°	1°
	25°	40°	50°	10°
Red.....	0°	9°	11°	2°
	15°	9°	13°	4°
	25°	17°	25°	8°
	30°	25°	45°	20°
Blue.....	0°	9°	10°	1°
	15°	10°	13°	3°
	25°	12°	15°	3°
	30°	20°	40°	20°

TABLE X

A. SHOWING THE COLOR LIMENS AT STANDARD AND DECREASED ILLUMINATIONS WITH WHITE AND WITH BLACK SCREENS

Stimulus	Point on Horizontal Temporal Meridian at Which Limen was Taken	White Screen		Black Screen	
		Limen at Standard Illumination	Limen at Decreased Illumination	Limen at Standard Illumination	Limen at Decreased Illumination
Yellow ...	0°	22°	25°	28°	30°
	15°	25°	50°	35°	45°
	25°	50°	80°	42°	60°
	30°	80°	125°	60°	90°
Green....	0°	22°	25°	28°	30°
	15°	26°	36°	35°	43°
	25°	30°	75°	75°	220°
Red.....	0°	13°	20°	10°	14°
	15°	19°	35°	13°	19°
	25°	30°	55°	23°	35°
	30°	50°	330°	29°	58°
Blue.....	0°	17°	22°	10°	12°
	15°	25°	40°	12°	17°
	25°	35°	60°	18°	25°
	30°	40°	90°	30°	60°

Table X. shows the color limens at both standard and decreased illuminations when white and black screens are used, at the fovea and at points 15°, 25°, and 30° in the horizontal meridian on the temporal side.

Table XI. has been compiled from Tables IX. and X. to show how much greater the limens were for white and black screens at decreased than at full illumination; how much of the effect may be ascribed to the reduction of the amount of colored light coming to the eye; and how much to the increased induction of the screens. It will be seen from the results of this table that the loss of the sensation in intensity due to the increased brightness induction is much greater than that caused by the reduction in the amount of colored light coming to the eye.

TABLE XI

A. SHOWING HOW MUCH GREATER THE LIMENS WERE WITH WHITE AND BLACK SCREENS AT DECREASED THAN AT STANDARD ILLUMINATION AND HOW MUCH OF THIS EFFECT MAY BE ASCRIBED TO THE REDUCTION IN THE AMOUNT OF COLORED LIGHT COMING TO THE EYE AND HOW MUCH TO THE INCREASED INDUCTIVE ACTION OF THE SCREENS

Stimulus	Point on Horizontal Temporal Meridian at Which Limen was Taken	White Screen			Black Screen		
		Total Amount Greater	Amount Due to Decrease in Amount of Colored Light Coming to Eye	Amount Due to Increased Induction of Screen	Total Amount Greater	Amount Due to Decrease in Amount of Colored Light Coming to Eye	Amount Due to Increased Induction of Screen
Yellow...	0°	7°	2°	5°	12°	2°	10°
	15°	28°	10°	18°	23°	10°	13°
	25°	45°	5°	40°	25°	5°	20°
	30°	75	15°	60°	35°	15°	25°
Green ...	0°	5°	0°	5°	10°	0°	10°
	15°	8°	1°	7°	16°	1°	15°
	25°	35°	10°	25°	180°	10°	170°
Red.....	0°	11°	2°	9°	5°	2°	3°
	15°	26°	4°	22°	10°	4°	6°
	25°	38°	8°	30°	18°	8°	10°
	30°	305°	20°	285°	33°	20°	13°
Blue.....	0°	13°	1°	12°	3°	1°	2°
	15°	30°	3°	27°	7°	3°	4°
	25°	48°	3°	45°	13°	3°	10°
	30°	70°	20°	50°	40°	20°	20°

It was shown in Table III. that quite a great deal of brightness induction is caused by the change in brightness relation between color and screen produced by decreasing the illumination. Table VIII. shows how much this induction narrows the limits of sensitivity to the four colors used. Table XII. shows how much the limens are raised when the illumination is decreased by the inductive action caused by the change in the brightness relation between stimulus color and gray screen of the brightness of the color at standard illumination.

TABLE XII

A. SHOWING HOW MUCH THE COLOR LIMENS WERE RAISED AT DECREASED ILLUMINATION BY THE INDUCTION OF THE SCREENS WHICH MATCHED THE COLOR AT STANDARD ILLUMINATION

Stimulus	Point on Horizontal Temporal Meridian at Which Limen was Taken	Limen with Screen of Brightness of Color at Decreased Illumination	Limen with Screen of Brightness of Color at Standard Illumination	Amount Limen was Raised by Change in Brightness Relation Between Stimulus and Screen Caused by Decrease of Illumination
Yellow.....	0°	20°	20°	0°
	15°	32°	32°	0°
	25°	40°	40°	0°
	30°	65°	116°	51°
Green.....	0°	20°	20°	0°
	15°	28°	40°	12°
	25°	50°	190°	140°
Red.....	0°	11°	11°	0°
	15°	13°	24°	11°
	25°	25°	48°	23°
	30°	45°	150°	105°
Blue.....	0°	10°	12°	2°
	15°	13°	16°	3°
	25°	15°	23°	8°
	30°	40°	55°	15°

4. THE INFLUENCE OF CHANGE OF ILLUMINATION UPON THE ACTION OF THE PREËXPOSURE ON THE LIMENS AND LIMITS OF COLOR

The brightness of the preëxposure exerts an influence upon the color observation because the eye carries over an after-image from the preëxposure into the color observation. If, for example, the preëxposure is to black, a white after-image is

aroused which fuses with the succeeding color sensation and strongly reduces its saturation. The effect of preëxposure is especially strong in the peripheral retina because a very strong brightness after-image is aroused in the peripheral retina by a very short period of stimulation. It is very difficult for the writer to predict from the data she has at hand with regard to the effect of change of illumination upon the sensitivity of the peripheral retina to the brightness after-image just what will be the effect of change of illumination upon the action of pre-exposure on the color sensitivity of the peripheral retina. But even though there be no change in the sensitivity of the peripheral retina to the brightness after-image with change of illumination, it is obvious that there will be some effect of the change of illumination because of the change in the brightness relation of the preëxposure card to the colored stimulus. In case the stimulus light is gotten by reflection from pigment surfaces, this change of brightness relation is due to the shift in the brightness of the colors produced by the change in the illumination. In case transmitted light is used as stimulus, the brightness of the stimulus color is independent of changes in illumination and will remain constant; but a change in the brightness relation of stimulus to preëxposure will occur because the preëxposure will lighten or darken with change of illumination. The writer hopes to make the quantitative investigation of this point the subject of a future study. At present she can only point out that if a guarantee is wanted that the effect of the brightness of the preëxposure is eliminated from the results of the observation, the preëxposure must be to a gray of the brightness of the color and the illumination of the room must be kept constant.

IV. Conclusion

The foregoing results show how strongly the changes in the illumination of the visual field influence the color sensitivity of the peripheral retina, particularly when the stimulus is surrounded by a white field. They also show that the influence of surrounding field can not be eliminated even by means of a campimeter screen of the brightness of the color unless some

means be had of keeping the general illumination of the room constant. It is obvious without further comment how important it is that a method be devised to standardize this factor. . The preceding experiments indicate that without this standardization, no experiment can be repeated from time to time under the same conditions relative to any one of the brightness factors that influence color sensitivity. Results thus obtained are far from comparable. As was stated earlier in the paper a method of standardizing was described in an earlier paper in this volume of the REVIEW.[1]

[1] See footnote, 2, p. 1.

It was the writer's intention to have had the present article precede the one in which the method of standardizing is described, but owing to limited space in the July number the Editor was compelled to use for that number the shorter article.

NOTE ON A RETRIAL OF PROFESSOR JAMES' EXPERIMENT ON MEMORY TRAINING

BY HARVEY A. PETERSON

Illinois State Normal University

The experiments referred to may be found on pages 666–7 of Vol. I. of 'The Principles of Psychology.' The material chosen for the training was the first and second books of Milton's 'Paradise Lost,' while for the tests Tennyson's 'The Coming of Arthur' and 'Guinevere' were used. The subjects were Mrs. Peterson and myself. As we learned different poems, each could hear the other's recital. In the preliminary test 16 lines of Tennyson were learned each day for six days, the passages being consecutive, barring one or two unsuitable passages. These were also the arrangements of the final test. The training consisted of the same amount of 'Paradise Lost' per day for 29 consecutive days. The time of learning was kept uniform. Seven normal school students, three boys and four girls, acted as control subjects, taking only the tests. The following table gives the results. The figures are minutes

TRAINING SUBJECTS

	Training Averages			Test Averages		
	Prelim.	Final	Gain, Per Cent.	Prelim.	Final	Gain, Per Cent.
H.A.P.	27.26	20.61	24.4	20.3	13.6	33
M.H.P.	17.30	20.37	−17.7	18.5	10.6	42.7

CONTROL SUBJECTS

'The Coming of Arthur'				'Guinevere'			
Subj.	Prelim.	Final	Gain, Per Cent.	Subj.	Prelim.	Final	Gain, Per Cent.
E.R.	15.73	10.31	34.5	D.B.	16.85	20.63	−22.4
B.H.	12.35	9.46	23	G.K.	16.02	16.66	− 4
H.F.	24.74	17.51	29.2				
C.J.	35.53	24.04	32.3				
L.W.	25.06	21.12	15.3				
Average Improvement 26.8				Average Improvement −13.2			

and fractions of minutes. Where percentages are given, they are percentages of improvement.

In calculating the improvement in training, averages of the first six and the last six days were compared.

The large gains made by all except one of the control subjects who learned 'The Coming of Arthur' was due partly to the fact that the part learned in the final test was not so difficult as that learned in the preliminary test.

After the average improvement of the control subjects has been subtracted, H.A.P. made a net improvement of 6.2 per cent. in the tests, which is about one fourth of the improvement made by him in training. M.H.P. made an improvement of about 56 per cent. in the tests by a similar calculation. In the training no lasting improvement was made. Nevertheless there was certainly a large transfer of training here.

The improvement of both training subjects is ascribed to getting practice in methods of verbatim memorizing commonly considered by psychologists to be the best, such as learning by reading the sixteen lines over as a whole time after time rather than learning piecemeal, reading rapidly after the sense has been grasped, skeletonizing the thought, and others.

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